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ENGINEERING EDUCATION AND TRAINING AS A TECHNOLOGY TRANSFER PROCESS FACILITATING ECONOMIC DEVELOPMENT

by

© Pramod Bahadur Shrestha

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Doctor of Philosophy

in

ENGINEERING MANAGEMENT

DEPARTMENT OF MECHANICAL ENGINEERING

Edmonton, Alberta

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FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled ENGINEERING EDUCATION AND TRAINING AS A TECHNOLOGY TRANSFER PROCESS FACILITATING ECONOMIC DEVELOPMENT submitted by PRAMOD BAHADUR SHRESTHA in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY in ENGINEERING MANAGEMENT.

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DATE 25 APRIL 95

This work is gratefully dedicated to my parents: To my father for his leadership, inspiration and encouragement and to my mother for her love, thoughtfulness and kindness. They have always been my light of hope in my quest for scholarship.

ABSTRACT

This study explores issues associated with the technology (knowledge) transfer function of academic institutions, with particular reference to developing countries.

Although the idea of an important link between technology transfer -- economic development -- and the role of engineering education institutions as important institutional agencies of such transfer -- is not new for the developed countries, it is far from being a reality in the institutional context and development experience.

The study involved two distinct stages. In the first stage, relevant literature on the different technology transfer initiatives of American universities were reviewed and analyzed. In particular, the land-grant model of technology transfer was explored. The second stage involved field study in India. This work focused on soliciting perceptions from IIT (Indian Institute of Technology) faculty and associated individuals, on the institutional development and the technology transfer functions of an engineering education institution.

An emerging technology transfer focus is redefining the role and scope of academic institutions in the developed and the developing countries. Results of this study suggest that the most difficult but ultimately the most effective response to technology transfer initiatives (both in the developed and developing countries) deals with the attempts to integrate technology transfer efforts with faculty roles.

The findings of the study suggest that six major issues have to be addressed while initiating technology transfer activities from engineering education institutions. They are: (1) Issue of institutional leadership (entrepreneurial and technology transfer). (2) Issue of integrating technology transfer activities with the mainstream functions of the institution i.e. teaching and research. (3) Issue of the modes of technology transfer partnership and its effects on the internal institutional patterns of work and working relations. (4) Issue of funding and the respective role of the government, industry and business. (5) Issue of curriculum adjustment. (6) Issue of faculty reward, promotion and incentive policies.

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Chapter 1

SETTING THE CONTEXT FOR THE STUDY

Introduction

Technology has always been at the center of the development process, and engineers have played a major role in managing technological innovation as an instrument of change and progress. Technology has come to be universally recognized as fundamental to economic growth and development (OECD, 1992; UNCTAD, 1992; World Bank, 1991).

Technology transfer from in-house laboratory success to the market place, and from one enterprise to another, within or across national boundaries, constitute critical and distinct processes. From the point of view of technology transfer, three attributes of technology are important: Hardware, Software and Organization. Hardware represents the tools which extend people's physical capabilities. Software embodies analytical procedures and design data in order to operate the hardware. The organizational attributes cover social roles and interaction between people.

In discussions on economic growth and development, exclusive attention has been given to the visible physical inputs (World Bank, 1991; OECD, 1992). The invisible technological attributes embodied in human skills were generally disregarded. OECD (1992) articulates that over the greater part of this century the choice of technologies and the shaping of the technological trajectories have been dictated almost exclusively by considerations of labor and capital productivity, cost and competitiveness. Abramovitz (1956) and Solow (1957) provide powerful evidence of the impact of technological change on the economy. Solow (1957) dramatically showed that nearly nine-tenths of the growth of per capita income in the United States of America over the four decades prior to 1950 owed its origin to technological progress. Inputs of capital and labor were responsible for only one-tenth of the growth.

Development even in its narrowest sense needs at least one major input in addition to efficient technology per se: a parallel development of technical manpower. That is where the role of engineering education and training comes into the picture. Engineering institutions must be fully integrated in any technology transfer development efforts designed to promote economic development. In most of the developing countries, we see failure in this process. For example, in the case of a developing country like Nepal, the massive increases in engineering education expenditure during the 1980s were followed by sluggish economic growth (World Bank, 1989). This suggests a need for an alternative approach and vision of identifying the role and impact of engineering education and training in the technology transfer process and economic development.

In this climate of disappointed expectations, it is not surprising that a serious rethinking of the roles and function of the engineering education and training systems is evident. Increasingly, such rethinking has to take into account the new and intensified relationship of engineering institutions with other sectors of society, including, business enterprises and industries and the community.

The failure of traditional concepts in technology transfer process to explain a rapidly changing work culture, technological development and the social world calls for a redirection of effort, for the opening of new avenues of inquiry. This study is designed to address these challenges by proposing a framework in which engineering institutions can develop practices and organizational units that will help them to be actively involved in the process of technology transfer.

Background information about technological development in India and Nepal

Technological development in India

In 1950 with the appointment of the Planning Commission, India ushered in a period of planned development where science and technology became important components of the whole national planning process. India did not, however, start from scratch in building its scientific and technological capacity when it became independent in

1947. In addition to colleges and universities providing education in liberal arts, there existed in India, prior to 1947, a number of organizations dedicated to the promotion of science and technology such as the Indian Association for the Cultivation of Science founded in 1876, the Institution of Engineers founded in 1920, and the National Institutes of Sciences founded in 1935 (Morehouse and Gupta, 1987).

Of the several Commissions and Committees convened before 1947 that advised the Government to train people on an adequate scale for modernization, the most important was the Indian Industrial Commission of 1916-18 (Chandrakant, 1976). The Commission considered it essential that technical education should be provided to build up an industrial community capable of achieving industrial development for India. The Commission also recommended the establishment of advanced technological institutes.

Another important committee composed of leaders of science, industry, and finance in India was appointed by the Government in 1945 to consider the scope and number of higher technical institutions that would be required for post-war industrial development in India. The committee, known as the *Sarker Committee*, recommended that not less than four higher technical institutions modeled after the Massachusetts Institute of Technology (MIT) should be established in different regions without delay (Chandrakant, 1963., Sebaly, 1972).

The First Five Year Plan (1951-1956) gave importance to the setting up of a scientific infrastructure. It aimed at setting up of new national laboratories and research institutions and training of personnel for manning the research institutes and running industries (India, Planning Commission, 1951). The first Indian Institute of Technology (IIT) as planned by the Sarker Committee was set up in 1951 at Kharagpur. This Institute was fully funded by the Government of India without any foreign assistance.

During the Second Five Year Plan (1956-1961) efforts were directed to strengthen research facilities; coordinate research programs in various national laboratories; and train and generate technical manpower in sufficient number and ensure its proper utilization

(India, Planning Commission, 1956). In the 1950s and 1960s, perhaps the most explicit and comprehensive formulation of India's science policy is found in the Scientific Policy Resolution of 1958, which was introduced in the Indian Parliament. This resolution asserted :

> 1. to foster, promote, and sustain, by all appropriate means, the cultivation of science, and scientific research in all its aspects-pure, applied and educational;
>
> 2. to ensure an adequate supply within the country of research scientists of the higher quality, and to recognize their work as an important component of the strength of the nation;
>
> 3. to encourage, and initiate, with all possible speed, programs for the training of scientific and technical personnel, on a scale adequate to fulfill the country's needs in science and education, agriculture and industry, and defense;
>
> 4. to ensure that the creative talent of men and women is encouraged and finds full scope in scientific activity;
>
> 5. to encourage individual initiative for the acquisition and dissemination of knowledge, and for the discovery of knowledge, in an atmosphere of academic freedom;
>
> 6. and, in general, to secure for the people of the country all the benefits that can accrue from the acquisition and application of scientific knowledge (Rahman, 1973).

The Third Five Year Plan (1961-66) was primarily aimed at expanding research and training facilities in engineering and technology. Four additional IITs at Bombay, Madras, Kanpur and New Delhi were in the initial stages of establishment by 1961.

During this plan period, India received valuable aid from foreign countries and international agencies in the establishment and development of her Institutes of Technology. The Bombay IIT was assisted by the former USSR and UNESCO; the Madras IIT by the Federal Republic of Germany; the Kanpur IIT by the United States and the Delhi IIT by the United Kingdom (Chandrakant, 1976). The five IITs are apex institutions for the highest forms of engineering education and research. Incorporated as institutions of national importance, they offer bachelors, masters and Ph.D. courses in a wide range of engineering disciplines. Student enrollment at each IIT is about 1500 at first degree level, and 800 at postgraduate and research level (Chandrakant, 1976).

A deliberate policy to develop as many engineering institutions as possible for postgraduate studies and research was formulated and implemented particularly during the Third (1961-66) and Fourth (1969-74) Plan periods (India, Planning Commission, 1974).

The Fifth (1974-79) and the Sixth (1980-85) Plan appreciated the role played by science and technology in the development of the country. A close nexus between science and technology and education was envisaged in the Sixth Plan (India, Planning Commission, 1980).

In 1983 the Government also published the "Technology Policy Statement" and the main purpose of the Statement was to give technological development a clear direction as regards the growth of indigenous technology and the acquisition of technology from outside (Heptulla, 1986).

The Seventh Plan (1985-1990) highlighted the lack of coordination between various scientific and technical organizations as the main cause which was preventing the technological/scientific benefits to reach the masses. The Plan document also articulated the importance of establishing linkages between different sectors of education, scientific research, technology development, productive activities in agriculture, industry, etc., and government decision-making structures (India, Planning Commission, 1985).

During the last four decades since independence, India has made a substantial progress in capacity building in science and technology and has done much better at transferring skills and knowledge with external aid institution modeled for example after Massachusetts Institute of Technology (MIT) in the case of IITs and adapting them (Nayar, 1983). But it has made little progress in meeting the basic needs of food, shelter, health and employment of the rural people (Morehouse and Gupta, 1987).

For India, technological self-reliance implied that she must produce her own scientists and engineers for design, development, research, teaching and all other advanced scientific and technical activities. When the Second World War ended, a scheme of overseas scholarship was instituted under which brilliant young Indian students were selected and sent to the United States, United Kingdom and other countries for advanced study and research. Under the scheme, over 1000 scientists and engineers were trained abroad and brought back to staff India's national research laboratories, engineering institutions, industry and government organizations (Chandrakant, 1976). Moreover, the Five-Year Plans demanded a large number engineers for design and developmental work in the industry. This area of technology transfer, whether through education and training abroad or implantation of models of developed country engineering institutions overseas (as in the case of IITs), has received little attention in research literature in the field of technology transfer and economic development. Individuals who have studied abroad may be an effective technology transfer "change agents". This study examines how engineering education and training can be used as effective technology transfer process to foster domestic technological capabilities.

Nepal: Development of the Institute of Engineering

General Economic Situation

Nepal started its planned development efforts in the mid 1950s after the inception of the democratic system in the country. After more than 30 years of economic planning, certain basic ground work has been laid for an extensive social and economic infrastructure. However, the productive sectors of the economy have barely kept pace with the population growth (World Bank, 1991a). The result has been a stagnation in the real per capita income and a continuation of widespread poverty, unemployment and underemployment.

With an average per capita income of $ 190 (U.S.), combined with a life expectancy of about 52 years, infant mortality of about 111 per 1000 births, and adult literacy of only 35 percent, Nepal is one of the poorest and least developed countries of the world (World Bank, 1990). Nepal is extremely dependent upon agriculture as the primary source of sustenance, income and employment. Agricultural contribution is about 55 % of Gross Domestic Product (GDP), accounts for about 80 % of export and employs about 93 % of the workforce (World Bank, 1990).

The development effort in Nepal with its emphasis on a reduction of unemployment and underemployment through support for the agricultural sector and the establishment of basis economic infrastructure for the development of other sectors has been constrained by skilled manpower shortages (World Bank, 1989). Skill shortages together with inadequate manpower planning and associated inefficiencies in manpower utilization have been a major contributing factor for the delays experienced with the implementation of development projects in all sectors of the economy. The lack of skilled engineering manpower has also been one of the principal reasons for poor maintenance of infrastructure and capital equipment. More generally, technical skill shortages throughout the economy have constrained growth and expansion of employment opportunities (World Bank, 1989). It is in this context, the role and impact of the Institute of Engineering (IOE) to produce skilled engineering manpower comes into sharper focus.

Institute of Engineering

The establishment of the Institute of Engineering in the current form dates back to 1971 when the New Education Plan System (NESP) was introduced in Nepal. According to the NESP plan all post secondary education came under the Tribhuvan University system.

The broad institutional objectives of the Institute of Engineering are :

1. to produce engineering manpower of various levels needed for the development of the country,
2. to undertake various research and development works so as to strengthen the national engineering capabilities and solve national engineering problems, and
3. to provide technical services such as short term course and design and testing services (Institute of Engineering, 1991).

Since the formation of the Institute of Engineering in 1971, two new campuses have been built in the eastern and the western development region of the country. These campuses were established with foreign loan and grant assistance from the World Bank, the Asian Development Bank, UNDP/ILO and the Government of the United Kingdom. Currently the Institute of Engineering runs a four years Bachelor's degree in civil engineering and preparations are underway under the World Bank funded Engineering Education Project to offer four additional Bachelor level courses by the year 1995-96.

At present the Institute has formal academic links with the following academic institutions: Indian Institute of Technology New Delhi, Norwegian Institute of Technology, University of Calgary, University of Manitoba, University of Saskatchewan, University of British Columbia, and Industrial Occupations Promotion Center (ZGB) of the German Foundation for International Development.

The Institute of Engineering has a number of well equipped laboratories and workshops and about 400 highly qualified academic staff. However, it has yet to make a marked contribution to the country through research and development activities. Interaction with the engineering profession and with the industry are also lacking. Therefore this study will examine if the role of engineering education and training systems is an effective technology transfer process facilitating economic development.

Objectives of the Study

My interest to explore the potential of technology transfer embodied in human skills has evolved from my own experiences of working at the Institute of Engineering (IOE), Nepal with several foreign aided projects in establishing engineering schools since 1985. I was involved in two World Bank financed international projects as project chief and was directly responsible for strategic planning, implementation and coordination of the Staff development plan, infrastructure development and equipment procurement. This responsibility provided me with opportunities to visit various engineering institutions and training centers in North America, Australia and South and South East Asia.

In trying to establish a relationship between engineering education and training, technology transfer process and economic development, there are a few observations to keep in mind to emphasize the magnitude and complexity of the study.

My first observation is that our societies are going through a period of rapid and far-reaching technological change. Technological progress, the speed of communication, world competition, urbanization, international trade are just some aspects of the change which is posing crucial questions for societies, structure and habits.

My second observation is that this technological change in our societies represents a very considerable challenge for our education and training systems. In order to assess the effect of technological change on economic development and performance, all the analyses point to the decisive and fundamental importance of the education system (OECD, 1991). The role of engineering education and training in producing competent technical manpower holds the key to possible progress and determines each country's medium and long term prospect in world competition (World Bank, 1991).

My third observation is related to the problem of finding the best possible compromise between technological change and continuity. Whether it is aimed at young people or adults, engineering education and training has to prepare the individual for the technological change and challenges.

Most fundamentally, this study is motivated by a common concern in the developing countries to ensure that engineering education and training systems are responsive to the demands of technological change, and indeed contribute to the process of economic development (UNCTAD VIII, 1992).

The major purpose of the study is to investigate the institutional development of the Indian Institute of Technology (IIT) New Delhi, discuss the role of IIT New Delhi, in the technology transfer process and economic development and develop a conceptual framework of planning engineering education and training as a technology transfer process. The specific objectives are:

1. To study the institutional development of the Indian Institute of Technology (IIT) New Delhi, India and its role in economic development.

2. To examine the various technology transfer activities at IIT New Delhi and study the settings and academic tradition in which they exist, the changes they have brought to the Institute, and the responses made by the Institute to those changes.

3. To investigate faculty responses to various organizational issues concerning governance and management structure, academic programs, research and development, industry-institute linkages and other technology transfer initiatives.

There has been considerable debate since the early 1960s over the contribution of education and training to economic growth, and the basis for its measurement (OECD, 1992). On the issue of measurement, it is argued that the relationship between economic performance and human capital investment in the form of education and training can never be measured with any precision, there are simply too many factors involved, to say nothing of data deficiencies and other measurement problems (OECD, 1992). Against this background, the vital question of this study is not whether engineering education and training systems are a factor in effective technology transfer and economic development, but rather what needs to be done to improve their provision, by what means, in which directions and where responsibilities for action should lie.

Research Questions

General Research Question

How can the expertise and knowledge embodied in engineering education and training systems be conceptualized as a technology transfer process which can help improve economic growth in developing countries?

Subsidiary Research Questions

The following subsidiary objectives and questions will help to guide the study:

1. To examine the various technology transfer initiatives from American (United States) institutions of higher education.

   1.1 What are the general features and characteristics of different technology transfer mechanisms and how have they evolved?
   1.2 What are the lessons learned from the analysis of the technology transfer mechanisms and how can they be applied to plan technology transfer activities and responses in engineering institutions in developing countries?
2. To describe and analyze the institutional development of IIT New Delhi and discuss its present institutional setting and current policies related to technology transfer.
   2.1 What forms of engineering education and training projects have been attempted in India (the IIT initiatives)?
   2.2 What should be the role of an engineering education institution like the IIT in the transfer and management of technology in India? How can this role best be carried out?
   2.3 What are the lessons learned from the IIT New Delhi analysis and at the same time how can these experiences be reflected in developing a sound broad-based engineering education and training policy in developing countries like Nepal.
3. To propose a conceptual Engineering Education-Technology Transfer Model with particular focus on developing countries like Nepal.
   3.1 What is an appropriate conceptualization of the planning process and Why?
   3.2 University/Engineering institution administrators in the developing countries are likely to find themselves facing the need to be responsive to change in the academic tradition and to make policy, organizational, and resource allocation changes to respond to technology transfer.

How should such changes be made? Who are the possible "actors" and what are their roles?

3.3 Are engineers part of/or necessary for effective transfer of technology?

3.4 What are the responses and roles of engineering education institutions toward technology transfer and economic development?

Significance of the Study

Since one of the objectives of the study is to analyze the relationship of human capital embodied in the engineering education and training systems with technology transfer and economic development, the results of the study have potential for making contributions to the development of theoretical knowledge for successful technology transfer and adaptation.

As noted earlier, studies on the role and impact of engineering education institutions in the technology transfer process are few. A scholarly goal of the study is to contribute to this important area of research.

The need to assess the effectiveness of engineering education and training system in the process of technological change and transfer is important because these institutions are increasingly under scrutiny for the role they can play in the process of technology transfer and economic development. In this context the findings of the study may have direct implications for the practice of administration at the Institute of Engineering, the only institution of higher studies in Nepal involved in training engineers. The IIT New Delhi case study will highlight aspects of engineering institution operations that may require attention; which may help administrators in their plan to improve the performance of the institution to meet the challenges of technological development and change and technology transfer. The institutional study of IIT New Delhi will also provide examples of successes and failures in managing engineering institutions and teaches some lessons that can inform us as we adapt to current technological changes and innovation.

The multi-disciplinary approach of the study may also benefit other researchers who intend to explore and extend knowledge on the relationship between engineering education and training , technology transfer and economic development.

The study is intended to help administrators of engineering institutions in developing countries understand and meet the challenge of technology transfer and the internal and external changes they have to make for designing broad-based institutional responses to technology transfer initiatives.

Limitations of the Study

The research is exploratory and is subject to the limitations of small sample research. The major limitation of the research sample is that it will only investigate the institutional development of IIT New Delhi in India. Since only one case study is investigated, there is no guarantee that the projects/institutions are representative of a general population of engineering institutions in the developing countries. This limits the generality of the research.

Interviews were used to collect the field data for investigating the institutional development of IIT New Delhi. This process assumes that interviewees have the ability to remember events in the past and to report events that they might or might not have observed. Published documents will ameliorate, but not totally eliminate the limitations associated with recall and accurate reporting of past events by interviewees.

The participation of the researcher in the interview process can also introduce a bias in data gathering and analysis. It is hoped that the potential bias of the researcher will be limited by the use of a specified framework for the collection and analysis of the data and by providing the participants the opportunity to review and provide feedback on the themes/notions derived from their interviews. However, there is no guarantee that another researcher examining the same data would arrive at the same conclusions.

Although the research design of this study is subject to limitations, it would appear appropriate given the level of knowledge of the phenomenon being studied. As Schendel and Hofer (1979) wrote:

> The choice of sample-size and data gathering methods will usually reflect the state of evolution of theory on the topic in question. For example, in exploratory research little is known about the territory, and so it is almost impossible to frame detailed questions about variables and relationships of importance beforehand. . . . It is usually necessary to use observation and unstructured interviews, coupled perhaps with secondary data from documentary sources. Since causal relationships are also not known at this stage, the research usually has to be longitudinal . . . the typical time and resource constraints, usually mean that the sample size must be very small (sometime n=1), that site selection is important, and that such selection be done in a non-random manner, with a preference for either leading or average organization (p. 390).

In this study the IIT project in India is selected as they are considered to be engineering institutions of national importance and excellence in Asia.

Definitions of Terms

Although the term technology transfer is relatively new, the business of moving technological ideas between originators and implementers has been going on almost since time began. One of the fascinating phenomena of the post-World War II period has been the burgeoning growth of activities in the field of science and technology (Stewart, 1978). In the 1950s and 1960s the popular dominant view was about industrialization 'short cut' and quick economic development with the import of foreign technology from the developed countries.(Soete, 1988, Rosenbreg, 1976, Singer, 1988). During that period, the notion of technological change was viewed as a global and more or less continuous process. Development was viewed essentially as a cumulative unidirectional process--a race along a fixed track--where catching up was merely a question of relative speed. The role of the use of imported technology from the developed countries as an industrialization 'short cut' process was the main focus of the "mechanistic" view of the process of economic growth and development (Jamison, 1988). From the early 1970s researchers started to stress the role of technological change as a disruptive process from a social and cultural perspective with changes in direction and deep structural transformations, in contrast to the mechanistic notion of technological change (Stewart, 1978).

Matkin (1990) concluded that the late 1970s was a watershed for the history of technology transfer in research universities in America. He further argued that

> Before that, technology transfer from universities to industry occurred largely through traditional processes: students who graduated and went to the industry, publication of the results of university research, and faculty consulting. "Knowledge transfer" is perhaps a more accurate description of the result of these processes. Beginning about 1977, however, there was a sharp increase in the number and activity of new transfer mechanisms. . . . Industrial sponsorship of university research grew, both in absolute volume and as a percentage of the total of research support funding. Universities increasingly were drawn into regional economic development plans through such activities as real estate projects and technical assistance programs. All this activity signaled dramatic change. . . . This new activity was called by a new name, *technology transfer* --a term that quickly gained currency, even though it was not well defined (p. 305).

Technology Transfer

Technology transfer embraces a wide range of variables of interest to economists, sociologists, anthropologists and managers. However, the term lacks precision because it is used in so many ways (Matkin, 1990).

Researchers concerned with the process of technology transfer belong to wide variety of disciplines and have diverse views about the process typical to their respective field. As a result, there is little uniformity in their definitions and conceptual distinctions regarding the transfer process.

An examination of the literature reveals that a wide range of activities are included under the label of technology transfer, which immediately leads us to take a critical look at the very fundamental issue -- that of definition.

Economists have long recognized that the transfer of technology is at the heart of the process of economic growth, and that the progress of different regions, in both developed and developing countries depends on the extent and efficiency of such transfer (Mansfield, Romeo, Schwartz, Teece, Wagner, and Brath, 1983). In other words, the economic treatment of technology transfer keeps in mind the economic goals. The literature of economics has a traditional tendency to classify technology in dichotomous terms such as appropriate versus inappropriate from the transferee's or host country's perspective (Dasgupta, 1979), labor-intensive versus capital-intensive from the nature of technology perspective (Lall and Streeten, 1977) and small-scale versus large-scale from the economic of scale perspective (Schumacher, 1973).

Sociologists are concerned more with the effect that the process of technology transfer has on social living than the economic goals of technology transfer (Zhao and Reisman, 1992). They view the role of technology transfer as a critical vehicle to aid in developing the capacity for individuals and societies to cope with modernization and the constant change that accompanies it (Chatterjee and Ireys, 1981). Sociologists define the transfer of technology (diffusion of innovation) as a social process by which a technology is communicated through certain channels over time among the members of a social system (Rogers, 1962).

Anthropologists viewed technology transfer from a broader perspective and within the context of cultural evolution. They looked upon the transfer process as change in the patterns of culture and society. The successful technology transfer simply constitutes a special case in the whole broad process of cultural and social change (Foster, 1962). Anthropologists view technology as inert and passive. By itself it does nothing. Only when people use a technology in some way does it have an impact on human life and society. Therefore, they argued that we cannot say anything about the actual effects connected with a particular technology until we understand why and what people do with it (Foster, 1962).

For Gruber and Marquis (1969) the transfer of technology must mean the utilization of our existing technique in an instance where it has not previously been used; for Chakrabarti (1973) technology transfer can be viewed as the generalized process of information transfer between science, technology and actual utilization.

Brooks (1966) has offered a wider definition of technology transfer. He has defined transfer of technology as a process by which science and technology are diffused throughout human activity. This can either be a transfer from more basic scientific knowledge into technology, or an adaptation of an existing technology to a new use.

Brooks (1966) extended his discussion to recognize two types of transfer, which he designates as "vertical" and "horizontal." Vertical transfer is the process by which technology is transferred from a more general to more specific, for instance, by the incorporation of a new scientific knowledge into technology which is not merely an adaptation but rather an embodiment of a "state of the art" into a system. Horizontal transfer comprises the adaptation of a technology from one application to another, as in the adaptation of a laboratory analytical instrument for an on-line process control, and hence this type of transfer corresponds to the more restricted notion of technology transfer.

"Technology transfer generally refers to disseminating information, matching technology with needs, and creative adapting of items for new uses" (Hough 1975, p.4). As one aspect of diffusion of technology, which is more random (Essoglou, 1975), technology transfer is the volitional adaptation of an innovation originating in one institution or system for use in another. The transfer process, however, is not linear in the sense that one begins with an invention and follow a prescribed path to adoption and adaptation. Rather, it tends to be fluid and ambiguous (Cortes & Bocock 1984, p.133), an experiment in innovation in which "the probability of failure is considerable, the cost of success high, and the final achievements likely to be different from the original goals" (Goldhor and Lund 1980, p.205).

Some common definitions and concepts of the term technology transfer are given below:

1. Technology transfer is the process by which a technology is transplanted or diffused from one locality to another. There are two classical dimensions of this transfer, vertical and horizontal. A vertical transfer of technology is defined as the transition from

the principle to practice, i.e. from pure science to its practical application. A horizontal transfer occurs when a particular technical element spreads from use in one context to use in another (Brooks, 1966, p.54).

2. The mechanism of technological transfer is one of agents, not agencies; of the movement of people among establishments, rather than of the routing of information through communication systems. People (the "human factor") accomplish technology transfer, not merely in the sense of the communication or transfer process itself involving the displacement of persons rather than concepts, requiring carriage by scientists and engineers rather than by publications or other messages (Burns, 1969, p.12).

3. Technology may be defined as the means or capacity to perform a particular activity. The transfer of technology must then mean the utilization of an existing technique in an instance where it has not previously been used. This transfer may be merely the acceptance by a user of a practice common elsewhere, or it may be a different application of a given technique designed originally for another use (Gruber and Marquis, 1969, pp. 255-256).

4. Technology transfer is the use of knowledge. When we talk about the transfer of technology, we really mean the transfer of knowledge. Knowledge can be stored and conveyed in many ways : The written word is knowledge; the spoken word is knowledge; computerized data banks are knowledge. Transfer does not mean movement or delivery. Transfer means the use of technology (Mogavero and Shane, 1982).

5. Technology transfer is defined as the moving of research and development (R & D) results out into the communities (Press, 1979, pp. 69).

6. Technology transfer is the application of technology to a new use or user. It is the process by which technology developed for one purpose is employed either in a different application or by a new user (Gee, 1974).

7. Transfer of technology is defined as the transfer of systematic knowledge for the manufacture of a product, for the application of a process or for the rendering of a service and does not extend to the sale or lease of goods (UNCTAD, 1985).

8. Technology transfer generally refers to disseminating information, matching technology with needs, and creative adapting of items for new uses (Hough 1975, p.4).

9. Technology transfer is the volitional adaptation of an innovation originating in one institution or system for use in another. The transfer process, however, is not linear in the sense that one begins with an invention and follow a prescribed path to adoption and adaptation (Essoglou, 1975).

10. Technology transfer can be viewed as the generalized process of information transfer between science, technology and actual utilization (Chakrabarti, 1973).

11. Technology transfer is the application of knowledge. It involves any geographical shift of technology (ideas as well as physical products): person-to-person, group-to-group, or organization-to-organization. There are two fundamental aspects to the transfer process. First, the technology must be created or discovered. Second, it must be expeditiously transferred to the appropriate receptor (Smilor and Gibson, 1991, p.3).

12. Technology transfer means a planned and rational movement of information and technique on how to perform some task, simple or complex. It should be distinguished from diffusion, the historic, unplanned movements of technical or social items from one country to another or from one user to another in the same system (Spencer, 1970, p.29).

13. Transfer of technology (diffusion of innovation) is defined as a social process by which a technology is communicated through certain channels over time among members of a social system (Rogers, 1962).

Technology transfer is defined in this study as a process of application of knowledge. When associated with academic institutions, technology transfer also means the transfer of the results of basic and applied research to the design, development, production, and commercialization of new or improved products, services, or processes (Matkin, 1990).

Table 1 indicates a synthesis of the various technology transfer models.

Table 1
TECHNOLOGY TRANSFER MODELS: A SYNTHESIS

Authors	Technology Transfer Models - Themes - Concepts	Perspective
Ogburns (1922)	Concept of "Cultural Lag". Cultural development lags behind technological development.	Social impact of Technology Transfer
Rogers (1962)	Movement/Diffusion of Innovation. Example: Hybrid seeds. 5 Stage Model. *Awareness *Interest *Evaluation *Trial *Adoption Concept of "Champion".	Socio-Economic
Mansfield (1966)	Why people accept technology transfer? *Profitability of the innovation.	Economic
Burns (1969)	Movement of people as Technology Transfer	Social
Streeten (1972)	Two Gaps Technology Transfer Model. *Communication Gap *Suitability Gap	Appropriate Technology
Schumacher (1973)	Concept of "Small is Beautiful"	Appropriate Technology. Socio-Politico
Bell and Hill (1978)	Concept of "local technological stock" and its role in technology transfer	Appropriate Technology
Bradbury (1978)	Contextual Fit Model. Source-Recipient compatibility.	Socio-Economic
Sirgy (1988)	Technology Transfer - Quality of Life Model. Concept explained in Maslow's Theory of Hierarchy of Needs	Politico-Economic
Smilor and Gibson (1991)	.Four Variable Model. *Communication *Motivation *Distance *Technological Equivocality	Socio-Economic

The term *economic development*, as it relates to institutions of higher studies, generally means institutional activities that are designed to encourage or promote economic development of a region, state or country (Matkin, 1990).

Organization of the Thesis

Chapter I describes the importance of the topic of technology transfer and the role of engineering education and training. It begins with a brief discussion on technological development of India and Nepal with particular reference to the development of engineering institutions. It also discusses the objectives, significance and limitations of the study and defines the term related to technology transfer.

Chapter II provides the background necessary for a comprehensive understanding of the concept of technology transfer and economic development. It reviews the literature on technology transfer models and examines the concept in three different themes namely: *economic development* concept, *diffusion* concept and *appropriateness* concept. A grasp of the various themes in the technology transfer model is needed to understand later discussions of the technology transfer activities and responses in institutions of higher education.

Chapter III deals with the research design and methodology of the study. It also describes the general questions and interview focuses explored during the interviews conducted with faculty members at IIT New Delhi.

Chapter IV reviews the different technology transfer initiatives and responses in American institutions of higher education. It summarizes eight different perspectives that deal with institutional setting and policies related to technology transfer activities at American universities.

Chapter V is concerned entirely with the institutional development of IIT New Delhi. It examines the governance and management structure, academic programs, research and development initiatives, curriculum and technology transfer linkages, industry-institute linkages and technology transfer administration at the Indian Institute of Technology, New Delhi. It presents a summary and examples of faculty views on a wide variety of topics related to technology transfer and management of the institute.

Chapter VI concentrates more directly on the various themes associated with technology transfer partnership between engineering institutions and the community.

Chapter VII deals with an engineering education - technology transfer conceptual model which will act as an analytic framework for taking effective steps to plan technology transfer activities and responses in engineering institutions in the context of developing countries. The relevance of the conceptual model in the context of Nepal is also discussed in this chapter.

Chapter VIII concludes the study by summarizing the lessons that can be drawn from this investigation of technology transfer issues and the role of institutions of higher education. It also provides recommendations for academic planners and administrators who are charged with the task of framing and organizing a coherent institutional response to technology transfer issues especially in the context of the developing countries.

Chapter 2

REVIEW OF LITERATURE

General Concepts

Technology and its transfer

There is widespread recognition that technological advance is a key factor contributing to long-term improvements in economic and social standards (OECD, 1991). Some fundamental questions that come to my mind are: What has enabled some countries to successfully transfer technology while fostering domestic capabilities while other countries have faltered? What are the attributes that makes them successful in obtaining the best results from the transfer of technology? Pointing out the complexity of effective transfer of technology, Rosenberg (1982) wrote:

> One of the most compelling facts of history is that there have been enormous differences in the capacity of different societies to generate technical innovations that are suitable to their economic needs. Moreover, there has also been extreme variability in the willingness and ease with which societies have adopted and utilized technological innovations developed elsewhere.. . . Clearly, the reasons for these differences, which are not well understood, are tied in numerous complex and subtle ways to the functioning of the larger social systems, their institutions, values, and incentive structures (p.8).

When we talk about examples of effective transfer of technology, Japan and South Korea comes up as outstanding example of a nations whose economic development or industrial growth has been based primarily on acquiring technologies from the United States (World Bank, 1991; OECD, 1992; Rosenberg, 1982). Rosenberg (1982) argued that "perhaps the most distinctive factor determining the success of technology transfer is the early emergence of an indigenous technological capacity" (p. 8.). He asserted that the Japanese success was based on their having emphasized the development of indigenous technological capabilities from the outset. Japan's rapid industrialization after 1945 was fueled by its aggressive accumulation of technical skills, which in turn was based on its already high level of literacy and a strong commitment to education, especially the training of engineers (World Bank, 1991).

Three essential elements namely: the concept of economic growth, the concept of diffusion and the concept of appropriateness are discussed in order to provide a composite picture for understanding the general theme of technology transfer and development.

Concept of Economic Development/Growth

The importance of technology at macroeconomic and microeconomic levels is well established. Economists have shown a very lively interest in a wide variety of questions concerning management of technology. They viewed technology as a major input requirement for economic development. A number of economic theories and models for explaining economic growth have been in existence for several decades. These techniques range from subjective explanations to various mathematical models. Four major economic growth theories and models are briefly reviewed below.

Growth and development are sometimes used synonymously in economic discussions. These terms have separate meanings. Economic growth is the measurement of changes in output, usually measured in gross national product or gross domestic product (Kuznets,1971). Economic development is the measurement of changes in output and changes in the technical and institutional organizations by which it is produced and distributed (Clower, 1966).

(1) The Smith/Malthus theory

Adam Smith (1723-90) was the first to examine manufacturing technology systematically in 1776. It found its classical expression in Adam Smith's book, The Wealth of Nations, which appeared in 1776. Smith wrote at the time of the industrial revolution in England when he could observe that western Europe was developing while many other areas of the world were not. In his book, The Wealth of Nations, Adam Smith

(1910) attributed increases in labor productivity to three major causes, the last being the invention of machines (new technology).

> This great increase of the quantity of work which, in consequence of the division of labor, the same number of people are capable of performing, is owing to three different circumstances; first, to the increase of dexterity in every particular workman; secondly, to the saving of the time which is commonly lost in passing from one species of work to another; and lastly to the invention of a great number of machines which facilitate and abridge labor, and enable one man to do the work of many (p. 7).

Smith discussed the efficiency that comes from specialization, division of labor and exchange.

Population growth was the dynamic element of the Malthusian Theory. Thomas.R.Malthus (1766-1834) believed that although wages and per-capita food supply might rise over the short run, this would only cause population growth to speed up and wages to fall back to the subsistence level (Gillis, Perkins, Roemer, & Snodgress, 1983).

(2) Ricardian growth theory

Writing at a time when the industrial revolution was well underway, Ricardo (1887) was more interested than Adam Smith in the direct consequences for the working class of the introduction of machinery. Ricardo (1887) asserted that new technology in the form of new machinery might create unemployment. Clearly, Ricardo was more concerned with the consequences than the causes of technological change. The Ricardian growth model emphasized the limits to growth is imposed by the ultimate scarcity of land. Unlike Smith and Malthus, Ricardo was concerned less about growth and more about income distribution and foreign trade. Ricardo emphasized that unless more land is discovered and cultivated or, more probable, unless food is imported cheaply from abroad, the limits to growth in income for nations and their citizens will quickly be reached. An expansion of the distribution of income between landlords and peasants composed an important part of his work.

Like Smith, Ricardo (1891) believed that growth resulted from what he called "accumulation", i.e., from capital formation. In the Ricardian model, inputs to the production process are divided into those fixed in quantity and those whose quantities can be varied: land is fixed; capital inputs are not. Growth can be possible only to a certain point. It will not continue infinitely because of the diminishing returns to labor and capital. Land at the margin of cultivation can not yield enough to pay the subsistence costs of labor, even after profit falls to zero. Expansion ceased. The system does not consider the possibilities of technological progress or the substitution of the variable factor, i.e. labor-and-capital, for the fixed one, i.e. land. It is felt by some that the Ricardian scenario, with its emphasis on the agricultural sector and the importance played by the fixed factor of land in determining income distribution and growth, has a striking relevance for many less developed countries (Bhagwati, 1967).

(3) Neoclassical Theory

The main opposing concepts of economic growth models differ regarding the assumption of substitutability between factors. The neo-classical school assumes that total labor input and capital stock in the traditional production function can be substituted. The relative price of factors is the only determinant of the optimal input combination. The fixed-proportions school assumes that labor input and capital are complementary (Eckaus, 1955). The relative price of factors has little influence over a choice of input combination.

In the Neoclassical theory, output growth can be decomposed into three separate sources: growth in labor, growth in capital and technical innovation itself (Solow, 1962).

The simple neo-classical production function with two inputs can be presented as:

$$Q = f(K, L)$$

Where Q is the (maximum possible) output produced, K and L represent the inputs of capital and labor, respectively, f(.) provides the form of relationship which is determined by technology, and it is assumed to be continuously differentiable (Ferguson, 1969).

The simple neo-classical production theory assumes substitutability of labor and capital, and a wide range of input combinations available to produce any given output. Technological progress is assumed by neo-classical economists to be neutral (Ferguson, 1969). This theory explains that the two factors --labor and capital-- do not contribute equal shares to product. The relationship explains the meaning of Solow's conclusion (referred as Solow residual)--that more than half of the increased output recorded in historical statistics seems to be attributable to technological and scientific advances rather than to thrift and capital formation (Solow, 1962). This means that technical change has a greater impact than the investment function. Solow tries to allow for the fact that new techniques get embodied in new capital goods.

(4) "New" growth theory

According to the so called "new growth theories", one can think of the economy as being composed of two distinct economic activities: first, the production of goods using capital and labor, as in the standard model; and, second, the production of knowledge (i.e. R&D) also using capital and labor (Romer, 1987). The proposition that investment in R&D and technological progress are essential for future growth has not yet been conclusively empirically demonstrated (OECD, 1992).

Nevertheless, economists generally agree that countries with higher output growth have also had higher levels of R&D investments and technical progress (Easterly and Wetzel, 1989). Despite present limitations, the "new growth theory" brings to the forefront the interaction between growth and technology-related tangible and intangible investment (OECD, 1992). According to OECD (1992), understanding of the concept of technology-related intangible investment embodied in the form of human skills is of crucial importance in order for us to understand the relationship between growth and technological progress. OECD (1992) argued that

> If the "increasing returns" associated with the technology related intangible investment can be successfully introduced into macro-economic growth analysis and modeling, the results may show more satisfactorily than they do at present that policies for technology have significant impact on growth and cannot simply be equated with micro-economic policies that improve static efficiency. (p. 184)

Another important concept linking technology and economic growth was developed by Schumpeter (1943). Indeed, Schumpeter's (1943) cyclical theory of economic growth proposed a central role for technology. Economic development, for him, was a process of "creative destruction," by which one system or cluster of technologies replaced another.

In their attempt to conceptualize the studies of technology transfer many economists treat technology as *exogenous* (Krugman, 1979, Finday, 1978, Rodriguez, 1975) in their models. Other theorists, however, view technology as *endogenous* (Dudley, 1974., Pugel, 1982). In conceptualizing technological change and its development and application fundamentally as a social process, not an event, OECD (1992) emphasized that

> New technologies do not originate outside the economic system and subsequently penetrate it. Rather technologies are invariably conceived, developed and diffused by means of long and costly investment. They respond to individual commercial demands and collective needs; they are developed and diffused under multiple economic constraints. Even as a starting hypothesis or an analytical basis, technological change cannot be treated as an exogenous factor in medium or long-term growth. (p. 15)

Concept of Diffusion

The issues involved in technology transfer have been treated by sociologists through the study of diffusion of innovation (Zhao and Reisman, 1992). Diffusion is used to include both the planned and spontaneous spread of technology. The systematic study of the diffusion process had its beginning in the late 1930s when sociologists investigated the spread of hybrid seed corn from agricultural scientists to Iowa farmers (Rogers, 1962). The diffusion research traditions can be viewed from two perspectives : Economic and Social.

(1) Diffusion: The Economic perspective

A study conducted by Griliches (1957) on hybrid seed corn is recognized as a classical study that provided a distinctive conceptual structure in the diffusion research traditions (Kranzberg and Kelly, 1978). Griliches (1957) major conclusion was that the entire process of diffusion, the process of adapting and distributing a particular technology to different markets, and the rate at which it is adopted was largely guided by expected profitability. His perspective was basically concerned with the reasons for propagator decision and behavior to enter certain markets or areas.

Mansfield (1966) was also concerned with the relationship of profitability to diffusion, though his focus was on the industrial sector rather than the agricultural sector. He concluded that the rate of diffusion of technology is determined, in large part, by four factors :

1. the extent of economic advantage of the new technology over older methods or products;
2. the extent of the uncertainty associated with using the technology when it first appears;
3. the extent of the commitment required to try out the technology;
4. the rate at which the initial uncertainty regarding the technology can be reduced.

(2) Diffusion: The Social Perspective

As noted above, Mansfield (1966) found that the process of technological diffusion was slowed by resistance to change. Barnett (1953), an anthropologist, has also dealt with this issue in a highly speculative social-psychological work. Bernett argued that a new idea must be compatible with the norms of the social system, and the adopter must perceive relative personal advantage before they adopt. In developing their innovation diffusion model, Rogers and Shoemaker (1971) suggested that the rate of adoption of an innovation or a new technology depends on the following factors:

1. Relative advantage: The degree to which it is perceived as better than the idea it supersedes. The greater the relative advantage, the faster the rate of adoption.
2. Compatibility: The degree to which it is perceived as being consistent with the existing values, past experiences, and needs of potential adopters. The greater the compatibility, the faster the rate of adoption.

3. Complexity: The degree to which it is perceived as difficult to understand and use. The less the complexity, the faster the rate of adoption.
4. Trialability: The degree to which it can be experimented on a limited basis. The easier the trialability, the faster the rate of adoption.
5. Observability: The degree to which the results of an innovation are visible to others. The easier the observability, the faster the rate of adoption.

Rogers and Shoemaker's use of the term "relative advantage" includes the economic dimension identified by Mansfield (1966), but also goes beyond it to embrace social-psychological considerations of advantage as well. Rogers (1962) used "innovation" and "technology" as synonymous. He outlined that in general, innovation that are perceived by receivers as having greater relative advantage, compatibility, trialability, observability and less complexity will be adopted more rapidly than other innovation. In elaborating the time dimension of the diffusion process (rate of transfer), Rogers (1962) also highlighted that if the number of individual or any decision making unit adopting a new idea/technology is plotted on cumulative frequency basis over time, the resulting distribution is a S-shaped curve. Thus there is a methodological similarity between the S-shaped logistic diffusion model and some of the models of industrial growth and economic development, developed by Schumpeter (1943) and Kuznets (1971).

In developing his "Neighborhood effect" model, Hagerstrand (1965) studied the spatial pattern in the adoption of subsidized pasture improvement innovations in Sweden over a 20 year period, relying on the probability assumptions of neighborhood effect. Comparing his results with empirical data, he demonstrated that not only does spatial proximity increase the probability of adoption but that simulation techniques and model of S-Curve growth are useful predictors of spatial diffusion of innovation. Hagerstrand also outlined the limitations of his neighborhood effect model and acknowledged that there are 'receptivity factors' which affect the spatial pattern and rate of adoption of innovations. These factors include cost, returns, attitudes, predisposition, and value systems. He termed these characteristics as modifiers of "neighborhood effect" and hence must be considered in any multivariate theory of transfer process.

One of the major questionable assumptions of the diffusion models discussed above is about the generalization regarding a homogeneous population of adopters. The models assume that everyone should adopt, that diffusion rates should be rapidly increased, and that rejection was an undesirable decision (Rogers, 1962). Unlike the view of "epidemic" models of diffusion of Griliches (1957), Mansfield (1961) and Rogers (1962), in which diffusion is considered as a process of imitation and its spread is affected by profitability and other economic considerations alone, the "threshold" diffusion model argues that adoption and diffusion patterns of a new technology are the result of explicit maximizing behavior of a heterogeneous population (Feder, Just and Zilberman, 1985).

Concept of Appropriateness

One of the earliest views about the problem of technology transfer and the possible inappropriateness of technology experienced by the developing countries were formulated by Eckaus (1955). In his analysis of factor proportions problems in developing countries featuring the Philippines, he expressed instances of engineers and experts from parent plants who were accustomed to working with western technology and hence preferred to operate with it in underdeveloped areas of the third world. Eckaus articulated that technological decisions and the pace of technical change affect all development processes--economic, social and political-- and, that they in turn, are affected by those processes. His main concern was setting out criteria for appropriateness. In doing so, he admitted that the use of any one technology is not an end in itself. Rather, the choice must be found in the goals and processes of development. These criteria for appropriateness are a concern not only with income and quantities of output but also with the way they are produced and distributed.

Since the early 1970s the question of appropriate technology for developing countries has received wide spread attention by many policy makers and researchers.

Schumacher (1973) who first introduced the concept of intermediate technology believes that developing countries need the kind of technology which, instead of making human hands and brains redundant, helps them to become far more productive than they have ever been before. He summarized the criteria he believed are necessary for appropriate technology as follows:

> they must be cheap enough for jobs to be provided in very large numbers and simple enough to be used and maintained by rural and small-town populations without sophisticated technical or organizational skills and with very low incomes. It follows that equipment of this kind will have to be provided largely from indigenous resources and employed largely to meet local needs.(Schumacher, 1973, p.76).

Many of the ideas behind intermediate technology are not unique to Schumacher. His unique contribution was to synthesize a wide array of material into a simple package with a broad scope for application (Willoughby, 1990). One tradition which made a direct contribution to Schumacher's thinking was that of Mahatma Gandhi and the Indian community development, or the "Sarvodaya" movement (Willoughby, 1990). In 1961, his "people-centered" approach to economics led Schumacher to conclude that those forms of industry or technology which discouraged the spontaneous mobilization of labor power, no matter how acceptable they appear from the perspective of mainstream economic theory, will ultimately hinder economic development where it is most needed (Schumacher, 1973).

Thomas (1975) investigated the choice of technology for an irrigation tube-well project in East Pakistan (now Bangladesh). He showed that a low cost program is more efficient than medium and high cost programs in terms of rate of return. He also articulated that the low cost program is better in terms of employment creation and training, distribution of benefits and the potential for creation of domestic small industry. However, the low cost program was rejected in favor of the medium cost program because such factors as the preferences of the donors, risk avoidance, appearance of modernity, operating procedures and established routines outweighed the development policy objectives in the actual decision-making for the choice of technologies.

Bhalla (1976) divided the specialists in the fields of technology and employment into two schools of thought: (1) those who believed that appropriate technology might best be achieved by selecting from the existing "shelf" of production alternatives, and (2) those who stressed the advantages of modern technical progress--capital/knowledge intensive by embodying the latest scientific advances. He concluded that , based upon their employment effects, the two viewpoints are complementary.

> the acquisition of new technological knowledge cannot be isolated from the existing knowledge base and current methods of production, while at the same time recourse to known technology is likely to open up new production possibilities. This interdependence between the static and dynamic aspect of the problem must be taken into account in drawing up any policy framework for the promotion and introduction of appropriate technology (Bhalla, 1976, p.203).

Frances Stewart, a British economist, has done extensive research on the relationship between technology and development in poor countries. Her study in Kenya on maize grinding technology revealed that the demand for hammer mill technology, although considered an attractive "appropriate technology," is going down while the demand for the roller mill, a product of high technology, is increasing (Stewart, 1978). The change in demand has been due primarily to the fact that people are prepared to pay more for the sifted product from a roller mill than the unsifted product from a hammer mill, thereby significantly altering the economic comparison of these technologies. The productivity of the sophisticated mill in terms of monetary value of its product became higher than that of the hammer mill, while its investment productivity was only slightly lower. Hence Stewart (1978) concluded that one cannot draw conclusions from the nature of production methods alone without also looking at the implications of consumption patterns (quoted as case study IV, Manandhar, 1992, p. 55).

Referring to certain setback to the widespread diffusion of appropriate technology, Stewart (1987) articulated that

> Although the need for appropriate technology is widely agreed upon, as evidenced by the enormous literature . . . and the many institutions which promote appropriate technology . . . the achievements in terms of actual use of appropriate technologies have been relatively small. A major reason for

> the relative failure of appropriate technology- in terms of actual on-the-ground investment- has been a near exclusive focus by those promoting appropriate technology primarily (and often exclusively) on micro interventions. . . . Unavoidably such interventions can only affect a very small proportion of the total investment decisions (p. 271).

Thus, in the 1990s argued Stewart (1987), logic dictates that the efforts of the appropriate technology movement primarily be placed on changing the policy environment in which appropriate technologies are to be diffused. But appropriate action cannot be conceived without a prior understanding of the nature of political power in any economy.

Stewart (1972, 1978) also argued that the question of choice of techniques in developing countries is more complex than the neoclassical growth model's approach, which regards the question of choice of techniques as consisting of choosing between techniques of differing capital and labor intensity.

The neoclassical model assumes that all economic activities are carried out under conditions of perfect competition. Capital and labor are each assumed to be homogeneous and substitutable. Only the relative prices of labor and capital are regarded as the determinants of the choice of techniques which producers will make to maximize their profit. In her criticism of the neoclassical model, Stewart (1978) observed that in order to achieve its simplification, the neoclassical model completely ignores the other factors that determine technical choice, such as the nature of product, scale of output, skilled labor requirements, material inputs, etc.

The nature of product, which is an important characteristic of techniques, depends on the income level of consumers, cultural factors, and requirements imposed by technology in use. As the income level of consumers increases, the nature and amount of products they consume also change. The same needs of consumers are fulfilled by a different set of products. Higher income also expands the market size. This will encourage producers to introduce new products into the market. New technologies will be developed to produce these new products. The old products become obsolete over time as consumers switch to higher quality products. Consequently, the old techniques also become obsolete. The neoclassical approach assumes that both capital and labor are each homogeneous and various combinations of capital and labor can be used to produce a given amount of the "same" product.

Stewart (1978) argued that techniques are not perfectly divisible. The more capital-intensive technologies tend to be designed for a large scale, and the more labor-intensive technologies tend to be designed for a smaller scale. Each technology requires different skill levels of labor. The quality of products can be different if they are produced by different techniques, and the quality of products is one of the important factors that determine a technology choice.

Stewart (1978) further noted that the range of techniques available to produce a particular good arises from the historical development of that particular industry. Each technique has a vector of characteristics consisting of product type, quality, scale of output, and resource use.

Riskin (1979) reviewed two decades of experimentation with rural intermediate technologies, after the failure of the great leap forward movement (1958-1960), in the People's Republic of China. Riskin found that the rapid development of the five industries: iron and steel, cement, chemical fertilizers, and machinery and power, in the rural areas led the People's Republic of China to the accomplishment of the development objectives, reducing unemployment or underemployment, increasing output, reducing capital requirements, and saving foreign exchange.

Ranis (1979) defined appropriate technology as a relative concept--relative to society's resources and goals. He emphasized institutional and social factors as well as prices as important in determining a choice of technology.

Hammod (1978) identified the following seven steps that are necessary in carrying out appropriate technology research and development.

(1) Problem and need identification

(2) Available alternative technologies and resources

(3) Analysis of the alternative technologies

(4) Design and adaptation

(5) Prototype development

(6) Testing, evaluation and modification

(7) Replication (Manufacture)

In encouraging the development and diffusion of appropriate technology it is helpful to distinguish between three sets of policy interventions (Kaplinsky, 1990). Kaplinsky further argued that those at the micro-level, influencing the behavior of individual enterprises, have received most attention. At the meso-level these policies are targeted at the sectorial level, for example, aiming to upgrade all sugar or brick producers, or encourage the widespread diffusion of fuel efficient charcoal ovens.

More recently, since the mid-1980s, there has been a growing awareness of the need to fashion macroeconomic policies to encourage the development and choice of more appropriate technologies (Kaplinsky, 1990). Whilst all these levels of intervention have a different role to play in the development and diffusion of appropriate technology, they should be optimally constructed to complement each other.

One issue often raised regarding appropriate technology is its definition. Jequier (1976) described that "assessing the appropriateness of a technology necessarily implies a value judgment both on the part of those who develop it and those who will be using it" (p. 19). Confusion also arises due to the number of adjectives that have been introduced to define the concept of appropriate technology: correct, optimum, adapted, labor intensive, low capital, low cost, intermediate, small-scale, indigenous, alternative etc.

Appropriate Technology has also been severely criticized. Herrera (1981) felt that appropriate technology which emerged after the 1960s lacked a sound philosophical base. Rybczynski (1980) described appropriate technology as an inverted pyramid with "a great deal of verbiage and speculation resting on a few accomplishment" (p. 13). He further articulated that appropriate technology movement became popular as it did not attempt to put forward a reasoned argument but appealed directly to the emotions.

Experiences of appropriate technology dissemination are mixed. Some authors argue that appropriate technology has often tended to be less advanced and has resulted in a widening of the technological gap between advanced and developing countries. Some see a need to integrate modern and traditional technology in developing countries to speed up the development process (Oshima, 1984).

The issue of appropriate technology is therefore strongly debated. Many are refining and redefining the concept and meaning of appropriate technology to suit their own needs. There is no consensus. More investigations on the impact of appropriate technology policies are needed, in particular, to explore the social-economic-political dimension of appropriate technology (Manandhar, 1992).

Education and Development

Questions are often raised regarding the validity of causal relationships between illiteracy and underdevelopment; however, the synergy between education and development is generally accepted (Ahmed, Ming, Jalaluddin & Ramachandran, 1992).

Nelson and Phelps (1966) studied the relationship of "human capital" in the form of advanced education to technology transfer and economic growth. They viewed higher education as an investment in people, i.e., that educated people are bearers of human capital, and account for technological progressiveness of society. Hayami and Ruttan (1971) also tend to support the analysis of Nelson and Phelps. They articulated that investments in research and education (human capital) provide a basis for technology diffusion, technological change and growth. After studying the history of agricultural innovations and diffusion in the United States and Japan, Hayami and Ruttan (1971) concluded that one of the major factors in a country's capacity to adopt agricultural innovations from elsewhere, as well as to diffuse indigenous technology, is investment in education. In this respect, there is a general optimism about engineering education and training as a vehicle for national development. But the question we have to look at is: "are there certain limitations or problems in educational strategies and reform efforts used to bring about certain expected outcomes?" In this context, the approach adopted in this study has focused on the institutional analysis of IIT New Delhi and to identify the areas of strengths and weaknesses of the IIT system in order to develop a conceptual model of framing and organizing engineering education as a technology transfer process.

Song (1984) identified the following nine major factors which have made an important contribution to the rate of economic growth of South Korea. The nine factors are:

1. The strong intervention of government for national development.
2. Cheap labor.
3. Export-led development.
4. Education.
5. Foreign assistance
6. The Confucian legacy.
7. The experience of Japanese colonialism.
8. Severe competition with North Korea
9. Cultural legacy.

Among the above variable Song (1984) identified education as the most important variable for national development of South Korea.

Chapter 3

RESEARCH DESIGN AND METHODOLOGY

Introduction

In this study qualitative research approach will be used to investigate the subject area. In qualitative research design, exploratory case study research approach is used to identify the role and impact of engineering education and training systems in the technology transfer process and economic development. Exploratory research is used to identify the phenomena of interest and describe their key characteristics (Schendel and Hofer, 1979). Lofland (1971) argued that the main application of exploratory research design is to build new theory as opposed to theory testing. He outlined that this type of qualitative approach in research design is useful for investigating the following types of questions:

1. What is going on here?
2. What are the forms of the phenomenon?
3. What are the variation in this phenomenon?

Patton (1990) articulated that qualitative research methods consist of three kinds of data collection: (1) in-depth, open ended interviews; (2) direct observation; and (3) written documents. Patton (1990) further described that the data from interviews consist of direct quotations from people about their experiences, opinions, feelings, and knowledge. The data from observations consist of detailed descriptions of people's activities, behaviors, actions, and the full range of interpersonal interactions and organizational processes that are part of observable human experience. Document analysis in qualitative inquiry yields excerpts, quotations, or entire passages from organizational, clinical, or program records; memoranda and correspondence; official publications and reports; personal diaries; and open-ended written responses to questionnaires and surveys (Patton, 1990, p. 10). Similarly, Mcmillan and Schumacher (1989) articulated that exploratory case study research include the use of observation, interviews, and documents.

In this study once the general research question was identified, the choice of qualitative research methods was logical because the question required the exploration of a process. Since the study was exploring an area of theory without specific hypotheses, the research had to build in openness to the unexpected, to new findings, and it had to retain a flexible design that fostered the exploration of refinements of meaning in a complex, tacit process.

The Case Study Approach as a Research Strategy

Case Study Defined

As a research strategy, the case study approach is used in this study. Indian Institute of Technology (IIT), New Delhi is selected as a "case". The case study method is frequently invoked as an important component of theory generation (Wilson and Gudmundsdottir, 1987). The literature of qualitative research strategies is filled with definitions of case study.

Merriam (1988) defined a case study as "an examination of a specific phenomenon such as a program, an event, a person, a process, an institution, or a social group. The bounded system, or case, might be selected because it is an instance of some concern, issue, or hypothesis" (pp. 9-10). Merriam further articulated that a case might also be selected because it is intrinsically interesting, and one would study it to achieve as full an understanding of the phenomenon as possible (p. 10). In providing a theoretical perspectives in case study research, Merriam (1988) also discussed the following four essential properties of a qualitative case study research: particularistic, descriptive, heuristic, and inductive.

Particularistic means that case studies focus on a particular situation, event, program, or phenomenon. The case itself is important for what it reveals about the phenomenon and for what it might represent. This specificity of focus makes it an especially good design for practical problems - for questions, situations, or puzzling occurrences arising from everyday practice. Case studies concentrate attention on the way particular groups of people confront specific problems, taking a holistic view of the situation (p. 11).

The *descriptive* characteristics focuses on the end product of a case study which is generally a thick description of the phenomenon under study. The description is usually qualitative in nature instead of reporting findings in numerical data.

Heuristic means that case studies illuminate the reader's understanding of the phenomenon understudy. They can bring about the discovery of new meaning, extend the reader's experience, or confirm what is known (p. 13). The *heuristic* quality of a case study is suggested by these aspects:

- It can explain the reasons for a problem, the background of a situation, what happened, and why.
- It can explain why an innovation worked or fail to work.
- It can discuss and evaluate alternatives not chosen.
- It can evaluate, summarize, and conclude, thus increasing its potential applicability (p. 14).

Inductive characteristics reflects that, for the most part, case studies rely on inductive reasoning. Generalizations, concepts, or hypotheses emerge from an examination of data - data grounded in the context itself (p. 13).

Likewise, Bogdan and Biklen (1982) defined a case as "a detailed examination of one setting, or one single subject, or one single depository of documents, or one particular event" (p. 58). Yin (1989) provided this definition:

> A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used. (p. 23)

Yin (1989) further argued that the case study method is preferred in examining contemporary events, but when the relevant behaviors cannot be manipulated. Comparing historical research approach and case study approach, Yin (1989) described that:

> ...the case study relies on many of the same techniques as a history, but it adds two sources of evidence not usually included in the historian's repertoire: direct observation and systematic interviewing. Again, although

> case studies and histories can overlap, the case study's unique strength is its ability to deal with a full variety of evidence - documents, artifacts, interviews, and observations. Moreover, in some situations, such as participant-observation, informal manipulation can occur. (pp. 19-20)

According to Yin (1989), case study research have at least four different applications. The most important is to *explain* the causal links in real-life interventions that are too complex for the survey or experimental strategies. A second application is to *describe* the real-life context in which an intervention has occurred. Third, an evaluation can benefit , again in a descriptive mode, from an illustrative case study - even a journalistic account - of the intervention itself. Finally, the case study strategy may be used to *explore* those situations in which the intervention being evaluated has no clear, single set of outcomes (p. 25).

Miles and Huberman (1984, a) used "site' and "case" interchangeably and indicated that:

> We use the word "site" to mean the same thing as "case." Both refer to the same phenomenon: a bounded context in which one is studying events, processes and outcomes. Note that a "case" could include a wide range of settings: a school, a program, a specific project, a network, a family, a community, and even the behavior of an individual over time in a specific environment. We prefer the word "site" because it reminds us that a "case" always occurs in a specified setting; we cannot study individual "cases" devoid of their context in the way that a quantitative researcher often does. (p. 28)

In contrast, Wilson and Gudmundsdottir (1987) argued that these definitions of case study research are intrinsically incomplete: they are all based on the assumption that a case is defined by its boundaries in time and space. Moreover, many evaluators and researchers assume that boundaries are predetermined (p. 43). They further described that there may be times when the boundary conditions of the "case" are well defined and researchers working with a well-articulated theoretical framework may well be able to pinpoint the phenomenon under investigation, identifying its theoretical or empirical boundaries. However, there are cases where the researchers do not set out to verify a theory, rather armed with a variety of explanatory concepts and interesting research questions, they set out to generate or elucidate theory. In such a situation, Wilson and

Gudmundsdottir (1987) observed that identifying the boundaries in time and space of a case is not a simple task. Likewise, Yin (1989) illustrated a fundamental problem in doing case study research - that of defining the unit of analysis (and therefore of the case) - and stated:

> Of course, the "case" also can be some event or entity that is less well defined than a single individual. Case studies have been done about decisions, about programs, about the implementation process, and about organizational change. Beware of these types of topics - none is easily defined in terms of the beginning or end points of the "case". (p. 31)

Regardless of the unit of analysis, a qualitative case study seeks to describe that unit in depth and detail, in context, and holistically (Patton, 1990).

Attempts to define case study often center on delineating what is unique about the research design (Merriam, 1988, p. 14). Merriam (1988) further noted that the uniqueness of a case study lies not so much in the methods employed (although these are important) as in the questions asked and their relationship to the end product. Stake (1981) takes this notion one step further and claims that knowledge learned from case study is different from other research knowledge in the following four important ways. Case study knowledge is (as quoted in Merriam, 1988, pp. 14-15) :

* More concrete -- case study knowledge resonates with our own experience because it is more vivid, concrete, and sensory than abstract.

* More contextual -- our experiences are rooted in context, as is knowledge in case studies. This knowledge is distinguishable from the abstract, formal knowledge derived from other research designs.

* More developed by reader interpretation -- readers bring to a case study their own experience and understanding, which lead to generalizations when new data for the case are added to old data. Stake (1981) considers these generalizations to be "part of the knowledge produced by case studies" (p. 36).

* Based more on reference populations determined by the reader -- in generalizing as described above, readers have some population in mind. Thus, unlike traditional research, the reader participates in extending generalization to reference populations (Stake, 1981, pp. 35-36).

In summary, then, the qualitative case study can be conceptualized as a process which tries to seeks holistic description and explanation of the phenomenon under investigation. This kind of research inquiry is based on a distinctive research design what Cronbach (1975, p. 123) calls "interpretation in context" which aims to uncover the interaction of significant factors characteristic of the phenomenon (Merriam, 1988, p. 10). As Yin (1989) observed, case study is a research design particularly suited to situations where it is impossible to separate the phenomenon's variables from the context. The whole phenomenon under study is understood as a complex system that is more than the sum of its parts and focuses on complex interdependencies not meaningfully reduced to a few discrete variables and linear cause-effect relationship (Patton, 1990).

Research Design

The research strategies required to achieve the purpose of the study included the following main features:

1. Literature review
2. Field study conducted at IIT, New Delhi, India
3. Interviewing
4. Direct observation

To obtain information relating to the research questions, the study investigated the perceptions of twenty key informants regarding the role and impact of engineering education institutions in technology transfer and economic development.

Essentially, in this study, considerable emphasis was placed on the literature review on the general features and characteristics of different technology transfer initiatives from American universities and the information gathered through conversation with faculty members at IIT New Delhi during the two months field study. The field experience was preferred because the attempt was to include the ideas and perspectives of those currently in practice and could provide a richer experiential perspective. More importantly, the field experience helped the researcher to sensitize the context and this proved vital for the quality of the interview process and the conceptualization being attempted in this study. The most substantive insights for this study emerged from the interview data and the literature review on the technology transfer initiatives from American universities.

This is quite a different approach than starting with a hypothesis and seeking support or rejection as in quantitative research. Instead the reasoning and thought processes of the individuals being interviewed were gathered. Experiences, decisions, and interpretations -- all added to the perspectives.

Similarly, by making a field visit to the case study "site" the researcher had an excellent opportunity for direct observation of various academic or other activities conducted at IIT New Delhi. According to Yin (1989, p. 91), such observations served as another source of evidence in a case study research and observational evidence was often useful in providing additional information about the topic being studied. During the field visit, the researcher also had an opportunity to organize a one day seminar (Technology Transfer Revisited: Models, Images and Myths) for the faculty members and students. The seminar was attended by about 50 people. This was a very useful opportunity to perceive reality from the viewpoint of someone "inside" the case setting rather than external to it. Many have argued that such a perspective is invaluable in producing an "accurate" portrayal of a case study phenomenon (Yin, 1989, p. 93).

Extensive use of documentary information about the case study was also initiated in this research. Specifically, emphasis was placed on reports published by IIT Review Committee (1986), annual reports of IIT New Delhi, report on placement of IIT graduates by the Association of Indian Universities (1985), IIT Education survey conducted by IIT New Delhi Alumni Association (1986) as well as some policy documents internal to IIT, New Delhi. In order to have unlimited access to all relevant program documents and records, official permission was sanctioned from the director of IIT New Delhi for the researcher to conduct his study at the campus. The researcher was attached to the department of management studies at IIT New Delhi. Similarly, literature which explains engineering education and training from various perspectives such as planning commission documents, international organizations (World Bank, UNESCO and UNIDO) and engineering journals was analyzed. As Patton (1990) has suggested use of documentary information also provides stimulus for generating questions that can be pursued through direct observation and interviewing. To make this point clearly, Patton states:

> Thus program records and documents serve a dual purpose: (1) they are basic source of information about program decisions and background, or activities and processes, and (2) they can give the evaluator ideas about important questions to pursue through more direct observations and interviewing. (p. 233)

Field Study

Data in the field component of the study were mainly obtained from interviews with twenty key respondents in India. This included eighteen faculty members from IIT New Delhi and two officials from the industry. The demographic profile of interviewees are indicated below in table 2:

Table 2

Demographic Data of Interviewees

Number of IIT faculty members interviewed	18 Professors -------------- 11 Associate Professors -- 4 Assistant Professors --- 3
Number of people interviewed from the industry	2 Managing Director, R&D firm ---1 Industrialist --------------------------- 1
Gender	Female -- 3 Male ----- 17
Educational qualifications of the interviewees	Ph.D. ------- 18 Masters --- 2
Average years of experience	14

Sample Selection

Earlier reading and observation had suggested that the most fertile area for investigation in the field of technology transfer initiatives from academic institutions would be internal -- within the academic institution (in this case within IIT Delhi). Other studies had concentrated on client groups, government, institute - industry partnership, markets, etc. (Dorfman, 1983; Enros and Farley, 1986; Powers and Powers, 1988; & Feldmen, 1994). However there was little literature on the attitude and incentive of the faculty and administration of the institute.

The sample for the study consisted of twenty key informants who were policy makers, planners, administrators, industry personnel as well as faculty members who were involved in some form of technology transfer initiatives at IIT Delhi. At IIT Delhi, an attempt was made to find who the crucial decision makers are in the area of technology transfer and include them as key interviewees. In addition to those who were directly involved in policy making, planning and administrative activities in the institute, faculty and department, three faculty members who were involved in some technology transfer activities were also included as key informants in the interview sample

In any technology transfer initiatives from academic institutions, faculty play an important role. As the study dealt mainly to understand the perceptions of faculty members in engineering education institutions on a number of issues related to technology transfer and the changes they believe technology transfer initiatives will make in the organization and management of the institution and also the study dealt exclusively with the internal problems and dynamics surrounding technology transfer activities from engineering education institutions, no senior government official and few industry personnel were interviewed. The researcher also had some problem of access in getting in touch with government officials and industry personnel. The industry personnel were selected mainly because of their familiarity and success in the management and transfer of technology in India.

Most of the interviews were of a semi-structured and open-ended nature and done in a conversational manner. Interview guides were used in collecting data from the key informants (see Appendices B and C).

The prime purpose of this research was to determine how expertise and knowledge embodied in an engineering education and training system could be conceptualized as an effective technology transfer process which can help improve economic growth in developing countries. All the interviewees were asked to express their thoughts on the main research question. In order to get a holistic picture of the role and impact of engineering institution in the technology transfer process, subsidiary questions were asked under various subheading such as governance and management structure, academic programs, research and development, patents and technology transfer, institute-industry linkages and curriculum and technology transfer.

The researcher spent some time with the faculty members discussing the concept and models of technology transfer initiatives from institutions of higher studies, and also observed the activities of the newly established Foundation of Innovation and Technology Transfer (FITT) at IIT New Delhi. This strategy helped to establish good rapport with the interviewees. All the key informants were senior faculty members at IIT New Delhi and were generally knowledgeable about the nature and role of various technology transfer activities and were able to base their views on substantial past experience.

The reason for open-ended, semi-structured conversational technique was to maintain maximum flexibility on the part of the researcher and the interviewees. Patton (1990, p. 281) indicated that conversational interview is a major tool used in combination with participant observation to permit the researcher who is participating in some programmatic activity to understand other participants' reactions to what is happening. Bogdan and Biklen (1982) expressed the same concern:

> You are not putting together a puzzle whose picture you already know. You are constructing a picture which takes shape as you collect and examine the parts. . . . (Concepts emerge) from the bottom up (rather than from the top down), from many disparate pieces of collected evidence that are interconnected. (p. 29)

This strategy helped the researcher to establish a comfortable environment and most of the interviewees came forward with their own insights which in some cases was the basis for further inquiry. In many cases, the same faculty member was also interviewed on a number of different occasions using the informal, conversational approach. This approach was particularly useful because the researcher stayed on campus which provided excellent opportunity for multiple interviews and was not dependent on a single interview with a respondent. Highlighting the strength of this type of approach, Patton (1990) stressed that

> Interview questions will change over time, and each new interview builds on those already done, expanding information that was picked up previously, moving in new directions, and seeking elucidations and elaborations from various participants. (pp. 281-282)

The researcher had some problem in tape recording interviews. Most of the interviewees appeared uncomfortable with tape recording. Only three interviews were tape recorded and transcribed verbatim and the rest were based on note taking. In order to minimize poor recall and poor or inaccurate articulation on the interview themes, the researcher did not have any problem to go back to the interviewees to confirm their views and opinions. In addition, the researcher involved himself as the main actor throughout the entire field study phase.

Data Analysis

Data analysis is an ongoing cyclical process integrated into all phases of qualitative research (Mcmillan and Schumacher, 1989). Bogdan and Bilken (1982) argued that

> Data analysis involves working with the data, organizing them, breaking them into manageable units, synthesizing them, searching for patterns, discovering what is important and what is to be learned, and deciding what you will tell others. (p. 153)

In this study, data collected in the way described above were analyzed through the process of content analysis. Patton (1990) defined content analysis as a process of identifying, coding, and categorizing the primary patterns in the data. Patton (1990) further articulated that the purpose of classifying qualitative data for content analysis is to facilitate the search for patterns and themes within a particular setting or across cases (p. 384). Initially developed for numerical methods of data analysis (Borg and Gall, 1983), content analysis was later used as well for non-numerical data (Merriam & Simpson, 1984). Currently, content analysis is one of the important methods for non-numerical data analysis (Berg, 1989).

The first step in data analysis was to organize the interview data into topics and files. For this purpose five main topics especially with respect to governance and management structure, academic programs, research and development, patents and technology transfer and curriculum and technology transfer were selected. Following Patton (1990) the content of the data was thus classified. He emphasized that a classification system is critical in content analysis and argued that simplifying the complexity of reality into some manageable classification scheme is the first step in content analysis.

The next step was to identify themes and categories based on inductive approach of content analysis. Inductive approach means that the themes and categories come from the data; they emerge out of the data rather than being imposed on them prior to data collection and analysis (Patton, 1990, p. 390). Inductive approach of content analysis includes two steps for analyzing data : *opening coding* and *axial coding* (Berg, 1989). Initially, identifying common themes was difficult. Each of the interviews was scanned and was grouped into five categories or headings. Berg (1989) described this step as opening (initial) coding which helps to initiate an analysis leading to the identification of certain categories or notions. These categories/notions came out from the research questions. The next step was to identify common themes around categories/notions identified through the initial coding stage which is termed by Berg (1989) as axial coding. In keeping with the previously described research design strategy, themes were not preset. As interviews data were analyzed, notes were kept of potential themes. As the data analysis part progressed, potential themes started to emerge. Constant personal reflection became part of the theme identification process. Patton (1990) addressed this issue in this way:

> The qualitative analyst's effort at uncovering patterns, themes, and categories is a creative process that requires making carefully considered

> judgments about what is really significant and meaningful in the data. Because qualitative analysts do not have statistical tests to tell them when an observation or pattern is significant, they must rely on their own intelligence, experience, and judgment. This sometimes leads to the making of the qualitative analyst's equivalent of Type I and Type II errors from statistics. (p. 406)

Themes emerged from the data. As suggested by Bogdan and Bilken (1982) the puzzle had to form from the pieces in the data. However, Miles and Huberman (1984, b) cautioned about the need to be skeptical in selecting themes:

> When one is working with the text, or less well-organized displays, one will often note recurring patterns, themes, or "Gestalts," which pull together a lot of separate pieces of data. Something jumps out at you, suddenly makes sense. . . . The human mind finds patterns so quickly and easily that it needs no how-to advice. Patterns just "happen" almost too quickly. The important thing is to be able to (a) see real added evidence of a pattern; (b) remain open to disconforming evidence when it appears. (p. 216)

Towards the end of the field study, potential themes were also discussed with two interviewees who were head of departments at IIT New Delhi.

Validity and Reliability

In this section, a general discussion of validity and reliability and a brief discussion on how their requirements are satisfied are provided. Within the qualitative research tradition, the truth value of research is measured against the standards of validity and reliability (Yin, 1989; Merriam, 1988).

Validity is a measure of the accuracy of the findings and the analysis while reliability reflects the extent to which one researcher's findings could be replicated by another researchers. More specifically, internal validity refers to congruence between the data and analysis and the social phenomenon under study. External validity is a measure of "whether a study's findings are generalizable beyond the immediate case study" (Yin, 1989, p. 38).

On the other hand, Lincoln and Guba (1985) argue that in qualitative study the concepts of validity and reliability have limited meaning; however, notions such as credibility, dependability, transferability and confirmability are relevant to a degree.

For the purpose of attaining credibility and dependability of the study, all the themes that emerged from the interviews were also discussed with some respondents to ascertain their views. Furthermore, perception checks were done continuously through each interview. This was done mainly to insure interpretations were correct and to ensure that full details were received from the respondents. I also discussed the data and its interpretations with two faculty members at the faculty of business, University of Alberta, who were engineering graduates from the IIT system in India. Lincoln and Guba (1982) emphasize that this process of going to the sources, which they called "member checks", (p.110) is the backbone of satisfying the credibility and dependability criterion in qualitative research.

Issues of dependability and confirmability were attended to by establishing good rapport with all the respondents by recognizing them as active participants in the research process, by relying on the dialogical process to uncover their ideas and by cross examining issues, concerns and ideas of various respondents to identify commonalties. In addition, the researcher stayed on the campus at IIT, New Delhi, for about 2 months which helped to establish a solid rapport with all the participants throughout the entire field study phase.

In the context of transferability or validity, similarity to the setting will be the determining factor in relation to degree of transferability of results of the case study to other contexts.

Chapter 4

TECHNOLOGY TRANSFER INITIATIVES OF AMERICAN UNIVERSITIES

Introduction

In this study technology transfer initiatives are referred to as any activities designed to accelerate transfer (application) of knowledge and technology from an educational institution to the society. Technology transfer when it is associated with institutions of higher studies means a process by which knowledge and technology are diffused through human activities and initiatives in order to increase and strengthen the contribution of the institutions to the economic development of the community and the society. Assuming that such a process is in place and its intensification is perceived as desirable, there is a significant opportunity for the universities to accelerate transfer of knowledge and technology and thereby establish a direct visible link with the society.

Much of the literature about the role of higher education in economic development in the United States goes back to the teaching era (1636-1940), which started in 1636 with the planning and founding of Harvard college by the Massachusetts Bay Company (Hensley and Cooper, 1992). A college at Yale, New Haven was established in 1716 and the college of New Jersey (renamed Princeton University in 1896) was founded in 1748 (Cowley and Williams, 1991). In 1755 the college and academy of Philadelphia (renamed University of Pennsylvania) was established.

In professional education, the college at Philadelphia pioneered by establishing in 1765 one of the first American medical schools. Columbia followed in 1767, Harvard in 1785 (Cowley and Williams, 1991). In the area of science and technology, West Point, opened in 1802, followed by Rensselaer Polytechnic Institute in 1826. These technical institutes were patterned after the French *ecoles* system of education

The traditions of the early Americans colleges were imported from Oxford and Cambridge (Trow, 1993). In the early days of America (1636-1776), Rees (1976) argued that the colleges were dedicated not so much to preparation for a vocation. They were basically interested in the refinement of gentlemanly qualities and their student bodies consisted primarily of the most privileged young men in American society.

Cowley and Williams (1991) identified 1776-1862 as a period of exploration in the growth of higher education in America. They argued that during this era educational reformers primarily fought for admission to the college curriculum of the new knowledge triggered by the burgeoning technological salutation. The country demanded more complex and more advanced institutions to provide not only undergraduate education but also graduate instruction and to promote research (pp.122-123). This period also marked the entry of German patterns into American higher education (Thomas, 1973).

The growth and development of American universities then progressed through two major wave of change.

The First Wave of Change (1862-1940)

U.S. Land Grant University Model

The first wave of major change in the growth and development of higher education in the United States came with the introduction of the Land Grant Act in 1862. The U.S. Land Grant Act was passed by the United States Congress in July 1862. This Act which was also commonly known as Morrill Act, which created the land grant colleges and universities, was indeed a landmark in American higher education (Trow, 1993). Many other authors have also acknowledged that the Land Grant Act had profound and significant implication for the growth of higher education throughout the United States (Matkin, 1990; Rees, 1976; Cowley and Williams, 1991; Johnson, 1985; Bezilla, 1981). The main purpose of the Act was to establish land grant colleges to provide educational support for agriculture and the mechanic arts. The Act establishing these colleges set forth their leading purpose in part as follows :

> "The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to agriculture and the mechanic arts, in such a manner as the legislature of a state may prescribe, in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions of life (quoted in Knoblauch, Law and Meyer, 1962, p.218)".

According to the Act, each state, upon acceptance of the provision of the Act, was to be granted 30,000 acres of land in the national domain for each senator and representative it had in the U.S. Congress. The State was to sell the land, permanently retain the proceeds, and use the income generated therefrom to endow one or more colleges. In order to satisfy the conditions of the land grant fund, the colleges had to provide the appropriate courses of study.

Cheit (1975) has observed that the full impact of the land grant movement was not felt in the U.S. until later in the nineteenth century. He argued that the Land Grant Act of 1862 was the key element in bringing about the growth of applied subjects mixed with liberal arts subjects that became one of the special characteristics of higher education in the United States.

Michael Bezilla (1981) in his book "Engineering Education at Penn State: A Century in the Land Grant Tradition" articulated that the aim of the Land Grant Act of 1862 was not just fostering work exclusively in agricultural education and research. Giving the example of the growth of engineering education and research in Pennsylvania State University, he emphasized that engineering was also an extremely important component of the Land Grant education at Penn State and most other schools in the land-grant system.

In developing an institutional viewpoint of the land grant system, Havelock (1986) described the system as the most elaborate, most ambitious, and, arguably, most successful effort to develop a structured macrosystem for knowledge development and use in the field of agriculture in the United States over the last 100 years. In his view the land grant universities, their experiment stations, and the Cooperative Extension Service together comprised a coherent and well-coordinated system for the generation, transfer and utilization of scientific knowledge about agriculture and its everyday practice

Tracing the growth and development of American higher education, particularly in the area of science and technology, Matkin (1990) argued that the growing criticism of higher education in the United States during the 1850s focused on the following three major shortcomings:

1. The failure to include more natural sciences subjects in the curriculum.
2. The failure to teach practical subjects that would prepare students directly for careers.
3. The failure to provide advanced training of the kind that could be obtained in European Universities.

Similarly Kerr (1994) emphasizes that during the same period, three great surges of activity put more stress on the labor market side: the land-grant movement with its emphasis on preparing engineers and other "useful" professionals, thus advancing production in industry and agriculture; the transformation of teachers' colleges into comprehensive colleges and universities, training mostly for occupations more tied to distribution and to consumption services; and the rise of the community colleges, concentrated mostly on vocational skills (p.56).

In the 1820s, the establishment of the Rensselaer Polytechnic Institute (established in 1824) started the process of establishing institutes of higher learning in the field of applied science for the diffusion of new knowledge among the people (Matkin, 1990). Matkin (1990) also argued that by the 1850s the natural sciences had established a clear foothold in the American college curriculum, aided by private endowments such as those establishing the Lawrance Scientific school (1847) at Harvard and the Yale's Sheffield Scientific School(1861). By the 1860s a practical and utilitarian emphasis was discernible in many college curricula, a trend encouraged by the land grant act of 1862. Bezilla (1981) articulated that the Act provided the financial support needed at that time to start new courses related to agriculture and engineering (called mechanic arts).

From a general perspective, the U.S. Land Grant model has the following important institutional-curricular features:

- Non traditional
- Service-oriented
- People's colleges
- Open to all
- Problem solving by the linkage of research and extension
- Publicly-supported

On the other hand, from a technology transfer perspective, agricultural extension/linkage program is an important characteristic of the Land Grant model. This characteristic together with other attractions of the Land Grant System such as emphasis on agriculture, the centrality of science and technology in the higher education system, open educational access and problem solving thrust by the linkage of research and extension is an important development in the growth of higher education in the United States. This also laid the foundation for a comprehensive system of public higher education.

According to Cowley and Williams (1991) the Land Grant movement profoundly influenced the nature of American higher education in two vital ways: it brought to fruition the attempts to diversify the educational range of American colleges by adding practical education to their curriculums, and it promoted the benefits of competition and diversity of control by stimulating the growth of public institutions (p.122). They also argued that the Land Grant Act also culminated the era of exploration, the long period during which American higher education searched for arrangements and methods that would most effectively serve the nation's unique educational needs.

Articulating the distinct feature of the land grant model, Johnson (1985) discussed that the post-Civil War America was probably unique in world history - a new continent of land crying for settlement, already rising use of machinery on farm and in shop, expanding urban market, a revolution in transportation by water and rail, a wave of utilitarianism and secularism, and unusually favorable natural conditions (p.146). Significant infrastructure already existed, with readiness to use it fired by a reform spirit generated before the war and a national spirit born of the war itself. He further argued that the early land-grant colleges were within the system, not outside or above it. They were in some respects the product, not the cause. Johnson (1985) also pointed out that the development of research capacities was the key to the success of the land grant movement in the United States. He described the role and the impact of the research culture as follows

> In the beginning, agriculture did not exist as a field of knowledge and professors of agriculture could not be hired except as suitably renamed chemists, botanists, or practicing farmers. In one sense, the federal grants had been premature; in another sense, they were a call to make good on an ideal. For teaching youth, more was needed than what every farm lad already knew; for aid to farmers, research had to discover new knowledge. . . . This kind of development - the kind that generates something to share - is the sine qua non of the university contribution to national development. That was what the early land-grant colleges also learned. . . . What has been called "the research culture" does not come easily, nor quickly. Appreciating its centrality is the first step toward a successful developmental role. (p.145)

Setting aside of land revenues and mandating the teaching of agriculture and mechanical subjects assured that the rural citizenry would have colleges to pursue practical education. In 1887, the U.S. Congress passed the Hatch Act, a measure requiring each land grant college to organize an agricultural and engineering experiment station in order to acquire and diffuse useful and practical information (Hensley and Cooper, 1992).

As these land grant colleges took on responsibility for the agricultural experiment stations in 1887 and agricultural extension service in 1914, the "ivory tower" image of American higher education started moving on an inexorable course toward a greater service to society and the marketplace. At the same time, the concept that the university should provide a home for research and graduate education was imported from Germany (Rees, 1976, pp. 86-87). Rees further articulated that from that time onward, the genius of Americans for combining advances in knowledge with advances in its use blossomed and made possible much of the country's technological leadership. Matkin (1990) also agreed that by 1910, a new type of university, the research university, was clearly established in the United States.

Boyer (1994) argued that higher education and the larger purposes of American society have been--from the very first--inextricably intertwined. In the Colonial college, teaching was a central, even sacred, function; the goal was to train the clergy and educate civic leaders (p. A48). Following the American Revolution, the mission of higher learning slowly began to shift from the shaping of young lives to the building of a nation. The founding of institutions such as Rensselear Polytechnic Institute in 1824 was an acknowledgment that America needed railroad builders, bridge builders, builders of all kinds, according to the historian Fred Rudolph (quoted in Boyer, 1994, p. A48). For Boyer (1994) the land-grant act of 1862 linked higher learning to the nation's agricultural and industrial revolutions. He is also quite amazed that less than a century ago, the words like reality, practicality, and service were used by the nation's most distinguished academic leaders to describe higher education's mission.

Kerr (1994) identified that the period (1865-1900) was very significant and higher education in the United States experienced its greatest period of growth. He argued that during this period the classical college gave way to the leadership of the public land-grant university and the private research university in response to political populism, economic growth in industry and agriculture, and the rise of science (p.71). Similarly, DeVane (1965) explained that by 1920 most of the top research university had reached a stage of maturity. DeVane wrote

> The organization as a whole had become compact and was certainly more orderly. The major department lines had been marked out, and within the department the hierarchy had been established, from the full professor at the top to the lowest instructor. The complex organization that was now the university was usually managed by a large bureaucracy presided over by a secular president who normally could not maintain his scholarship in his busy office. He in turn was responsible to a board of trustees, largely made up of alumni lawyers and businessmen. (p. 74)

Summary

The Morrill Land Grant Act of 1862, which created the land-grant colleges in the United States brought a new wave of reform and innovation unprecedented in the history of the American higher education system. Four important aspects of the land-grant movement are significant.

First, the land-grant colleges and universities began making heavy commitment to transfer of technology and knowledge from academic institutions to America's rural farming community. From a technology transfer perspective, the Agriculture Experiment Stations and the Cooperative Extension Service can be identified as the most important components of the land-grant movement.

Second, service to client groups (in this case farmers, rural residents, and consumers) was generally conceived as the foundation of the land-grant model.

Third, the partnership between the land-grant institutions and the user groups was relatively a direct one, the professional and the extension agents of academic institutions were to transfer information or technique directly to farmers and rural people.

Finally, in the history of American higher education, the land-grant model was the first federally-supported research program, and essentially the only federally-funded applied research program, until World War II (Buttel, Kenney, Kloppenberg and Smith, 1986).

The distinctions between land-grant universities and non land-grant state universities have become blurred over the last century (Anderson, 1976). Appendix A lists the land-grant institutions in the United States.

The Second Wave of Change (1940-1990s)

If the land-grant movement of the 1860s could be identified as the first wave of change, then the second major wave of change to hit the American higher education scene occurred during World War II and after. During World War II the federal government introduced several sponsored research project directly in the university. The Manhattan

Project and other war-related projects produced in university laboratories some of the most deadly military weapons that have ever been known (Hensley & Cooper, 1992). The project-based research efforts required by World War II had a very significant impact on the development of the industry-university research relationship. During World War II, universities joined government to create the world's most powerful research engine (Boyer, 1994).

In 1940 Vannevar Bush, president of the Carnegie Institution of Washington, led the formation of the National Defense Research Committee (NDRC). Bush convinced the government that not only could the scientists and engineers produce the new military technology needed to defeat Germany but also that they could do so with little help or supervision as long as enough money was provided (Matkin, 1990). In 1945 Vannevar Bush also published a book entitled *Science - The Endless Frontier* in which he initiated the concept of long-term planning for university research and basically described the terms of a contract between the research university community and the federal government. The result was the development of a clearly articulated federal science policy and the establishment of a number of government agencies whose major task was to allocate research funds to academic institutions (Matkin, 1990).

The National Institutes of Health (NIH) were established in 1944 to direct and encourage medical research. In 1950, the National Science Foundation (NSF) was created to direct project-based research in American institutions of higher studies. The founding of the National Science Foundation sparked a government-university partnership that still persists. Since then NSF has served as a major source of funding for higher education research in the United States. In the fifties, agencies such as the Office of the Naval Research, the Atomic Energy Commission (AEC), and the National Aeronautics and Space Administration (NASA) were established and they all depended upon university project research for much of their basic research needs.

With the establishment of various government agencies and commissions the government did send a clear message that it planned to begin direct funding of academic research in targeted areas. One set of concerns that was raised at that time revolved around the theme of control and autonomy of university researcher. The fundamental question was that if the government decided what research to fund, could the university researcher maintain the same degree of objectivity that society generally expected from academicians? Two distinct, almost competing views are discernible in the literature: one views this partnership as positive and necessary, the other points to the threat to academic freedom and university autonomy implicit in this relationship.

Various scholars like Thorstein Veblen (1918), Glenn Seaborg (1972), who was a University of California faculty member in the 1930s and the chairman of the Atomic Energy Commission (AEC) in the 1960s and Abraham Flexner (1930) noted with grave concern the transforming impact of government monies on the university. They were of the opinion that with this growing partnership there would be a degradation of the academic spirit. In an editorial in *Science*, Philip Abelson (1991) observed that:

> a particularly dismaying feature of the government-university interface is that relationships continue on a long-term course of evolving deterioration. In the early days after World War II, there was a high degree of mutual trust and an absence of bureaucratic requirement. Scientists had freedom to formulate and conduct their programs of research. Later the bureaucrats took over and placed emphasis on project research with highly detailed budgets and detail research proposals. That , of course, is the road to pedestrian research (p.605).

He also cited the proliferation of administrative requirements and regulations as a serious drag on the freedom and quality of scientific work in the university.

On the other hand Kerr (1994) argued that adding additional federal funds to higher education encouraged university researchers to have greater contact with the realities of the productive activities of society. Hensley and Cooper (1992) also observed that the discussion over government-university control of research in the post-war period was moot because science had evolved to the point that the simply organized, single-investigator research using only departmental resources was no longer capable of solving many of the problems of science and the nation. They further argued

> World War II only hastened the formation of a partnership and an administrative structure that was inevitable. By themselves, universities did not have the organization and resources to take the next steps to advance knowledge in certain disciplines. Only the federal government had the massive financial resources and the centralized power to concentrate the intellectual resources on the problems of applied weapon research. This research was essential to providing the empirical evidence needed by basic researchers for the expansion of their theories. A federal government-university partnership was necessary for both parties. (p. 99)

Rees (1976) observed that due to increasingly generous federal support, the United States attained a dominant position in scientific research and the development of a science-based technology that was the envy of the world.

The Sputnik Factor

The placing of Sputnik space satellite into orbit by the Soviet Union on October 4, 1957 also initiated a massive expansion of federal support for university research. After the Soviet Union launched Sputnik into space, colleges and universities were called upon once again-- this time to help rejuvenate the nation's institutions of higher learning (Boyer, 1994). The very title of the National Defense Education Act of 1958 clearly linked higher learning to the security of the country. Federal fellowship under the Act brought thousands of teachers back to campus to upgrade their skills and enrich instruction.

The NASA (National Aeronautics and Space Administration) effort after 1957 was such a massive undertaking that it eclipsed the complexity of all World War II projects including the Manhattan Project (Hensley and Cooper, 1992, p. 105). During 1957-1967, government support of basic research in the American universities increased from $155 million to $1,124 million - an increase of almost 725 percent (National Science Foundation, 1970). While the government financial support witness a massive growth over those 10 years, the corporate (industry) support for basic research in universities remained minimal. During 1957-1967, corporate financial support for basic research increased only by about

48 percent from $21 million to $31 million (National Science Foundation, 1970). This new partnership between academic institutions and the federal government, founded on massive federal support, changed the face of American institutions of higher education (Matkin, 1990).

Expanded Research Activities

In the United States, the war increased the awareness of the importance of academic research. The Sputnik incident and its aftermath also gave rise to a scientific and technological boom. Funds became suddenly available from federal and state governments for scientific and engineering research. Funds available to academic institutions increased significantly in the 1950s and 1960s, with a result that monies expended at universities for research and development increased from $334 million in 1953 to $2.6 billion in 1968 (quoted in Grayson, 1993, p. 186). The role of the universities in research has become so great that the most heavily supported, about 170 universities, which perform about 90 percent of all academic research in science and engineering, have become identified as research-intensive universities (Grayson, 1993).

The massive expansion of financial support for research have also created some controversies and conflicts about the desirability of close university-government or industry linkages. Some argue that it may have led to reduction of university autonomy vis-a-vis government or even industry (Rice, 1992; Grayson, 1993; Friedman and Friedman, 1984). One major issue is: Whether in the university-industry-government partnership, there exist unwarranted limitations on the traditional academic norm of the free flow of knowledge and information? Furthermore, most analyses of conflict of interest problems tend to focus with respect to the very conception of scholarship that an academic institution espouse. In an essay on the conception of American scholarship, Eugene Rice (1992) argued that the present conception of scholarship is much too narrow. Fundamental to this process was equating scholarship with research on the cutting edge of a discipline. Furthermore, Rice (1992) also articulated the shift in the conception of scholarship in the following manner

> Sometime after the mid-1950s, following the impact of the GI Bill of Rights and the launching of Sputnik, a major shift took place in the image of what it meant to be an academic professional. Scholarship became research; teaching and research became activities that competed for the faculty member's time. The term scholarship, if it was at all, referred to research, not teaching. Teaching became a derivative activity. (p. 118)

Shifting the attention to university-industry linkage, the 1970s was a difficult period for universities in the United States. Link between industry and universities were weakest in the early 1970s (Matkin, 1990). During the early part of 1970s, about two-thirds of all colleges and universities in the U.S. were either in financial difficulty or heading in that direction (Cheit, 1971). Industry support for universities in 1971 dropped by about 9 percent (Cowley and Williams, 1991).

The 1980s and the 1990s were revitalizing periods where more universities continued to develop sufficient research capacity to participate meaningfully in economic development and tried to adapt to the research needs of their environment. According to Geiger (1993), the 1980s turned out to be a time for research universities to exploit their inherent strengths and to bolster their resources. He identified the following two perceptible changes in public attitudes toward higher education during 1980s.

1. A greater appreciation of - and greater rewards to - academic quality. The clearest evidence of this was the strong demand for places at selective colleges and universities throughout the 1980s.
2. A growing concern about the international competitiveness of American industry and the explosive development of bio-technology.

Postscript: New Roles for Engineering Education Institutions

Engineering education in America evolved from a combination of borrowed and indigenous elements, which in many ways reflected the character of the continent. The collegiate plan of organization and most of the traditions of the professoriate can be traced back to older universities of England, which formed the models for the early arts colleges of the United States, while the emphasis and methods of research and the model of graduate education came from Germany (Grayson, 1993, p.265). Land Grant colleges and universities were established to stress the service mission of academic institutions to client group. A beginning was made in the 1860s (land-grant movement) to technology (knowledge) transfer from academic institutions to agriculture. A century later, in the 1970s, American research universities began a heavy commitment to technology transfer into industry (Clark Kerr, foreword in Matkin, 1990 p.xv). In his foreword, Clark Kerr also posed an interesting question: In doing so, will they help to save the economy or will they subvert the academy, or, more likely, some of both?

The relationships between higher education and its external constituencies will require careful adaptation to respond to the pressures of economic development. Some observers have expressed the fear that too much adaptation to external needs would lead to a degree of co-optation and subservience certain to destroy the cherished autonomy of higher education (Lynton, 1984, p.153). Others warn that too much stress on applied scholarship will weaken the universities' attention to fundamental and non directed research. Lynton (1984) further argues that the growing need for the interpretation of knowledge and for its more rapid dissemination and application requires more faculty involvement in applied research, technical assistance, and public information. In turn, this implies a substantial change in the internal value and reward system of higher education institutions. The pivotal issue for engineering education institutions as they approaches the twenty-first century is to "strike a balance between an adaptation which is too flexible and an adherence to tradition which is too inflexible" (quoted in Matkin, 1990, p.xv).

Technology Transfer Functions: Research University versus Land Grant University

A persistent criticism of the United States' research universities is that they are closed-loop systems, driven by internal incentives of publication and recognition for high-scientific activities which bear little or no relation to wider social and economic needs (Shapley and Roy, 1985). Smith (1992) argued that the research universities have not generally sought, or played, an effective role in technology transfer and economic development. He does note, however, that agriculture is an exception. In highlighting the role of land-grant model of higher education he stated that

> The land-grant institutions have brought knowledge to farmers as an important part of their mission (they have done less well in the promotion of the 'mechanical arts'). Partly for the reason that they have emphasized diffusion of knowledge rather than generating new knowledge, the agriculturists have often been second-class citizens in the universities. Some few exotic technologies have attracted the interest of leading scientists and engineers, but usually at a stage far removed from product development. Certain aspects of biomedicine have witnessed a merging of basic inquiry and product development, thus propelling universities and their medical centers into a significant role in economic development in some instances. (p. 29)

Broadly, Smith (1992) suggested that the university contribution to economic development can be viewed from the following two perspectives:

1. As a source of advanced training and research, the university system as a whole should be oriented toward its long-range goal of laying the basis for future development and advancing the goals of a civilized and learned society.

2. The university system should be more directly and fully engaged in the economic development process and in achieving related societal goals. More federal funding attention should be given to applied research and demonstration projects which will imply the reverse of actual federal funding trends since the late 1970s.

It is probably unrealistic, however, to expect that the research universities will become prominent instrumentalities of technology transfer - at least not for the myriad smaller companies so important to economic health (Smith, 1992, p. 30).

It is with this backdrop of the general trends in the historical development of U.S. universities and their relation with the government and industry, that the following technology transfer mechanisms that are most closely associated with economic development initiated by American universities will be discussed.

1. Industrial liaison or affiliate programs
2. Technical assistance programs
3. Business incubators
4. Research parks

Technology Transfer Initiatives

The technology transfer initiatives discussed in this section include industrial liaison programs, technical assistance programs, business incubators and research parks. Most of these technology transfer mechanisms from American universities have grown markedly since the late 1970s, and their growth is both an index and a result of the importance of technology transfer in higher education (Matkin, 1990). However,

> most universities move uneasily in this arena and lack the internal expertise to manage such activities effectively. They sometimes are uncomfortable in playing a role so visible in the community and thus subject to community scrutiny and controversy. Despite the risks of financial failure and negative community reaction, however, universities have markedly increased their involvement in these activities because they are often the most visible symbols of the university's potential value to the community and thus the best key to its continued support. (Matkin, 1990, pp. 267-268)

Foden (1985) identified three general factors prompting the explosion of technology transfer initiatives. They are:

1. Attempts by the government (both federal and states) and others to replace the lost jobs (traditional industries) by bringing in higher technology activities.

2. A general shift in responsibility for R&D funding away from the federal level to the state and local levels and to the private sector. One cause of the shift is an effort by the federal government to encourage more private sector participation in R&D.

3. A move toward joint efforts by public and private organizations (including university groups) that are concerned with economic development. These groups have found that they cannot accomplish significant economic development alone, and they recognize the very significant role that universities have played in successful economic development for example , the Route 128 area of Massachusetts; Silicon Valley in California; Austin, Texas; the Research Triangle of North Carolina; and other areas.

Foden (1985) also articulated that the technology transfer initiatives specifically address four types of barriers to technology transfer. The first is the lack of information and awareness of technology development and application opportunities on the part of the industries, the public, and educational research institutions. The second barrier is the under-utilization of resources of research institutions. The third one is related to the problems industry may have in tapping the skills of university faculty. The fourth barrier is the limited financial resources available to support R&D application in technology transfer

Industrial Liaison Programs

The aforementioned barriers notwithstanding, a variety of industrial liaison programs have been in operation in American universities (especially research universities) for many years. This mechanism is an important means by which universities or departments or schools within the universities establish formal relationships with industry. In 1948, MIT established the first formal industrial liaison programs. This was followed by Stanford University, which established a liaison program in the field of aeronautics and astronautics in the year 1955 (Matkin, 1990). According to Matkin (1990) and Powers & Powers (1988), in a typical industrial liaison program, corporate members, in return for an annual fee, are provided with "facilitated access" to the university and the research being done by the university or department. In general, such programs are an excellent means of establishing communications between a university or its department and industry.

In a study of industrial liaison programs in research universities in the United States, Tamaribuchi (1982) identified two types of liaison programs: general-purpose programs and "focused" liaison programs. General purpose liaison programs are designed to provide corporate members with access to a wide segment of the university and its research and to provide the university with the funds to operate the programs as well as unrestricted money for the furtherance of research or the support of graduate students (Matkin, 1990, p.183). Most focused liaison programs, on the other hand, operate within a more narrowly defined subject area or technology grouping.

In a detailed study of industrial liaison programs at the four research universities (MIT, Stanford, University of California, Berkeley, and Pennsylvania State University), Matkin (1990) outlined the following findings:

> 1. MIT has the oldest, largest, and best known general-purpose liaison program. It was started in 1948 and by 1987-88 had over 325 corporate members, a budget of nearly $8 million, and a staff of about 57, including some 20 liaison officers.

> The liaison officers are crucial to the success of the program. Each serves as the representative of a number of companies and is charged with facilitating the relationship of these companies with MIT.
>
> 2. Although it is often listed as a main purpose for the establishment of liaison programs, a desire to facilitate technology transfer is rarely the propelling force either for the starting of a program or for its continuation. By far the most frequent reason given for the establishment of a liaison program is the generation of financial support from industry for research, graduate students or junior faculty (p.208).
>
> 3. Although liaison programs exist primarily because of the support and effort of faculty members, many programs have developed nontenurable staffs to provide services, maintain contact with member firms, and carry out many of the administrative tasks that would otherwise fall to faculty members. Such staffs after awhile begin to have a life of their own and to demonstrate independence from other parts of the university. Few liaison programs are subjected to review and oversight by university administration.
>
> 4. At MIT, the programs were seen as key elements in a culture that supported relations with industry and technology transfer, although few saw the programs as a direct means through which technology was transferred. Some faculty members saw the program as a superficial bureaucratic substitute for what should have been a more direct and meaningful interaction.
>
> 5. Charging of membership fee in order to be associated with the liaison program implies denial of access to firms unable to pay the membership fee. This seems to run contrary to the popular notion of what a university stands for. Fee requirements often exclude those small, start-up, technology-intensive companies that would benefit most from membership.
>
> 6. The amount of faculty time required to relate to liaison program members and administer the programs acts to pull faculty into a new role. Relating to industrial sponsors is considerably different from relating to government patrons of research in that industrially supported research generally requires greater interaction between the sponsor and the university researcher. The type of research is also different, tending to be more focused and applied. Very few universities have adjusted their traditional reward system to encourage this kind of activity (pp. 212-213).

Powers and Powers (1988) also observed that MIT has had a university-wide industrial liaison program that has operated at a substantial level, but few other universities have been able to match this type of success with university-wide liaison programs (p.92).

Technical Assistance Programs

Most university technical assistance programs (TAPs) are designed to serve small to medium sized businesses in a defined geographical area by providing advice either through answering technical questions submitted by business owners or through on-site consultations to solve production or other problems (Matkin, 1990. p.245). In 1965, the

U.S. Department of Commerce initiated the State Technical Services Program (STS) as a technology transfer initiative based on the operation of the enormously successful Cooperative Extension Service (CES) of the land-grant model (Roessner, 1989). The Pennsylvania Technical Assistance Program (PENNTAP), administered by Pennsylvania State University was one of the first STS program initiated by a land-grant university. PENNTAP began with an appropriation of $200,000 from the state legislature in 1966 (Matkin, 1990). This appropriation marked a small shift in the balance of political power in the state away from big business and toward small business and this drive was in response to an increasingly powerful small business constituency. PENNTAP employs full-time, professionally trained technical specialists who provide direct assistance to businesses based on their expertise or by referring to a university expert or an information source. These technical specialists hold academic rank (although they are not faculty) and are considered to be members of the relevant academic departments. Their closeness to the academic departments helps the specialists to stay in touch with the latest developments in their fields and also become familiar with the expertise of the faculty members (Matkin, 1990, pp. 247-248). However, this situation may only be unique to PENNTAP. Feller (1992) on the other hand wrote that in practice, most of the technical assistance programs is provided by full-time staff whose interaction with academic programs and faculty members is limited.

"Can agricultural extension combined with research which was the fundamental concept underlying land-grant institutions be viewed as an appropriate model for industrial extension that are designed to promote technology transfer from engineering institutions?" In this respect Matkin (1990) argued that there are significant differences between the old agricultural extension and what is now possible in other engineering fields. He highlighted the following five points to support his view that the agricultural extension model is not applicable to the modern industrial/technical situation:

1. Agricultural extension always was heavily subsidized by federal and state funds. No such large scale subsidies are likely for industrial extension activities.
2. The target audience for agricultural extension - farmers - was easy to identify, even if geographically hard to reach. Potential users of an industrial extension service are much harder to pinpoint.
3. Agricultural extension confined its activities to a well-defined discipline that existed in organizational units within universities, that is, schools of agriculture. However, a comprehensive industrial extension service must include many disciplines and university departments.
4. The "product" dispensed by agricultural extension often are delivered to the farmer in usable form by an extension agent. The advice delivered to industrial users, however, often requires considerable adjustment and implementation before it can become useful.
5. Agricultural interests are much more organized and carried much more political clout than potential users of industrial extension services (p.250).

Feller (1992) also presented a similar viewpoint and argued that fundamental differences rooted in the character of competitive markets exist between the transfer of technology in agriculture and manufacturing. He further commented that political attention to manufacturing modernization through technical assistance programs is a response to criticisms that federal research grants produced benefits for a select number of (large) industries (and universities), and have largely ignored the needs of small and medium sized firms.

One of the main problems that TAPs have in common with other organizational forms associated with technology transfer in universities is the uncertain status of the professional staff who operate the programs and the way in which the institutional reward system is structured for them. Like many technology transfer mechanisms, TAPs exist on the periphery of the university, uncertain of their place and often unsupported by the administration (Matkin, 1990, p.249, 251). In most of the TAPs, technical specialists do not have faculty status, with no clear path of promotion and reward system. In short, universities rarely have personnel policies and performance incentives appropriate for attracting the best technical specialists (Matkin, 1990).

Generally most of the TAPs are taken as public service activities. They are intended to serve small businesses. They rarely have strong influence with university teaching or research function. Moreover, faculty at research university are generally more interested in working on advancing research frontiers than applying what is already known. The needs and aspirations of the faculty do not accord well with the activities and incentives of technical assistance programs. Indeed, Matkin (1990) has characterized the attitudes of the faculty as follows:

> Although most TAPs depend to some extent on faculty participation, few universities have a reward or compensation plan to encourage such participation. This is partly because of the unsettled question of whether it is appropriate for faculty, especially in research universities, to be involved in solving relatively low-level, applied problems. Burdened with this philosophical question mark and unable to provide a reasonable incentive for faculty participation, TAPs must depend on faculty volunteerism and thus are under severe constraints (p.249).

Business Incubators

Business incubator centers are mainly intended to provide an environment in which small or start-up business ventures may be nurtured during their crucial early stages when business failures are common. Incubators usually charge below-market rental rates and typically are located in existing, vacant buildings. They also offer a variety of services that include technical or business advice.

When business incubators are associated with universities, the benefits the former provide to new firms are enhanced (Matkin, 1990). Matkin (1990) further commented that university-sponsored incubator firms normally have access to university libraries and other facilities, often including sophisticated scientific equipment, for low fees on a per use basis. Faculty members of the sponsoring universities may also provide the firms with management and technical advice.

Businesses remain in incubators for various lengths of time, depending on their success and the rules of the individual facility (Powers and Powers, 1988). A 1985 study by the National Council for Urban Economic Development (NCUED) surveyed seventy incubators facilities and determined that "almost twice as many firms survive to move out as failed while there. This compares favorably to the general business environment, where roughly four times as many fail as succeed during their first years" (quoted in Powers and Powers, 1988, p.97).

The Benjamin Franklin Partnership program in Pennsylvania is an example of university-business/industry partnership in which four advanced technology centers have been established by the State to engage in cooperative research and development projects; provide education, training, and retraining programs in areas crucial to expansion of both established and startup firms; and provide entrepreneurial assistance services (Powers and Powers, 1988). Funds to establish business incubators are administered through the Advanced Technology Center (ATC) of the Ben Franklin Partnership located in the University City Science center (Matkin, 1990). Powers and Powers (1988) note that in 1985-86 under the partnership program, a total of $102.2 million ($21.3 million from the State of Pennsylvania and $80.9 million from consortia members) was used by the four technology centers to support 379 projects.

Like technical assistance programs, business incubators are primarily an extension of the service role of universities. They seldom are closely tied to the university's central missions: teaching and research. Their place in the university therefore often is undefined, subject to misunderstanding by the faculty, and in need of constant explanation and justification (Matkin, 1990, p.255).

Research Parks

While there has been no agreement on a precise definition of what constitutes a research park, the American based Association of University-Related Research Parks (AURRP) defines a university research park as a property-based venture with the following characteristics:

- Has existing or planned land and building specially designed for private and public research and development facilities, high technology and science based companies and support services; and,

> * Has a contractual and/or operational relationship with a university or other institution of higher education; and,
> * Has a role in promoting research and development by the university in partnership with industry, assisting in the growth of new ventures, and promoting economic development; and,
> * Has a role in aiding the transfer of technology and business skills between the university and industry tenants (Association of University Related Research Parks, 1990, p. 3).

The above definition indicates that the main characteristics of university associated research parks include four types of activities: research activities with the industries located at the park, training programs, high technology production and technology transfer from the university.

Many efforts have been made to establish research parks as a means of stimulating economic development. In most of the research parks, incubator space and service and technical facilities for startup companies are often provided. Tenants of such parks are often embryonic advanced technology firms engaged in research and development projects and companies engaged in light, clean manufacturing processes related to advanced technology, applied science, or engineering (Powers and Powers, 1988, p.78). The first university-related research park was the Stanford Research Park, founded in 1951 (Danilov, 1971). By 1983 the Stanford Research Park was fully leased and its 660 acres housed 80 tenants with a total of over 28,000 employees (Matkin, 1990, p.258). Stanford Research Park provides a model that many universities have tried to imitate, usually without success. Commenting on the reasons for failure, Matkin (1990) noted that:

> The failures may arise because Stanford's park grew out of a set of institutional imperatives and a culture supportive of industry-university relationships that do not exist on very many other campuses today (p.258).

Other examples of successful research parks cited by the Office of Technology Assessment includes the Research Triangle Park in North Carolina. The Research Triangle in North Carolina was established in 1959 and was patterned after Stanford Research Park (Foden, 1985). Although a few of these partnership have been spectacularly successful, not all efforts to copy the achievements of the Research triangle have been equally remarkable (Schmidt, 1984; Battelle Institute, 1983; Glazer, 1986). Schmidt (1984) commented that only 50 percent of the university-related research parks have been successful and found the following two main reasons for failure of research parks:

> One of the main reasons that about 50 percent of research -park ventures have not succeeded in getting out of the planning stages, or have become little more than high-quality industrial parks . . . is that their location offer no possibility for interaction with a high technology or scientific community, such as a university, a government facility or an industrial complex. . . . Also, many developers do not realize that a minimum of ten years and as many as twenty are usually needed to establish a base of local employers (p.37).

He also noted that it is absolutely critical to get commitment of a large, well-established company to establish a research park.

In assessing the reasons for the success of research park, the Battelle Institute (1983) observed that

> The more successful parks involve the university as a core resource, rather than as an "available" activity in the general area. Still, not all such state-generated activities have been successful. Research and science park projects sponsored by the universities themselves have failed in almost all cases. The projects sponsored (in isolation by major developers) have failed in a majority of cases. . . . The probabilities of success for these ventures increase dramatically when a community-wide, diversified approach is taken, involving active participation by the university, private developers, representatives of local high technology industries, and community leaders. When any one of these is missing, the chances for success decline rapidly. (p. 6)

Glazer (1986) also emphasized that for a successful research park initiative, a world class research talent, the infrastructure of a nearby metropolis, and a thriving financial community are essential (p.47).

Special Initiative: Boston's Route 128

In an essay on the growth of high tech firms on Boston's Route 128, Nancy S. Dorfman (1983) described the 'electronics revolution' that she saw coming to full fruition in American society after World War II. According to Dorfman, Massachusetts' high tech boom in the late 1970s close to Boston's Route 128 is found to have been largely indigenous and spontaneous, rather than the result of a concerted effort to attract industry. She further argued that Massachusetts' distinguished universities (MIT and Harvard) and their research laboratories (Digital Computer Laboratory, Draper Instrumentation Laboratory, Lincoln Laboratory, Cruft Laboratory, Artificial Intelligence Laboratory), an inherited technological infrastructure, the importance of agglomeration externalities and the good fortune of having home-grown firms (Digital Equipment, Data General, Wang, Honeywell, Prime) become the world's leading manufacturer of minicomputers were major contributors to the state's economic success. Comparing Boston's Route 128 and Silicon Valley, Dorfman (1983) presented the following findings:

> 1. Both began their take-off after World War II with heavy support from U.S. military and space programs. By the end of the War, Massachusetts contained the country's most distinguished combination of academic-based laboratories (mostly at MIT) supporting research at the frontiers of electronic and computer technologies, and also some well established electrical and electronics companies such as Raytheon and General Electric, both sectors heavily supported by government contracts. On the other hand, Silicon Valley had the important advantage at that time of proximity to the emerging aircraft and space industry which was to become the major customer for semiconductors and indeed, the only customer for integrated circuits for many years (p.312).
>
> 2. Academic centers of excellence are at the heart of both local economies. The MIT-Harvard axis at Route 128 and the University of California at Berkeley and Stanford at the Silicon Valley.
>
> 3. The early successes of a few individual entrepreneurs both in Massachusetts as well as in Silicon Valley powerfully influenced the direction and magnitude of regional development (p.315)
>
> 4. The most stunning parallel between the two regions is in the youthfulness of the dominant enterprises. Virtually all are children of the transistor-computer generation rather than headquarters or branches of pre-war giants in the electronics or office machines industries.

Dorfman (1983) also identified the following four points that would help planners and policy makers who seek to duplicate the Route 128 experiences in other regions:

> 1. Massachusetts' electronics boom occurred basically without the benefit of concerted efforts to make it happen by academic institutions, government bodies or other interest groups. This does not prove that such efforts are necessarily futile, but that they are far from crucial in some case at least (p. 315)
>
> 2. Academic institutions (like MIT and Harvard) provided the leadership in R&D efforts. It remains to be seen whether institutions of lesser rank can provide the same stimulus to innovation.

> 3. Massachusetts' industrial growth in electronics was started by new firms (not established names in the field of electronics). The new firms were especially prolific when it came to spinning off other new firms.
>
> 4. Finally, agglomeration externalities that accrue to firms from close proximity to others engaged in closely related activities in those rapidly evolving industries argue in favor of attempts to achieve a degree of specialization among high tech industries in a given region than diversity (p. 315).

Reinforcing the foregoing observations, Plosila (1987) has also argued that there is no single, successful formula in designing programs and initiatives that will promote innovation and technology transfer. Successful examples of university technology transfer initiatives are provided by California's Silicon Valley, Massachusett's Route 128 and North Carolina's Research Triangle Park. In many ways, Feldmen (1994) indicates that these examples are unique: Silicon Valley relied on strong university-industry interaction; Route 128 benefited from a strong entrepreneurial tradition; and, in large part, Research Triangle Park succeeded because of the direct efforts of the state government (p. 102).

Organized Research Centers: Growth and Implications

The establishment of organized research centers in American universities brought about important internal changes in university administration. This section discusses the factors prompting the proliferation of research centers, outlines some of the obstacles universities are dealing with, and explores some of the examples that are becoming popular. It also identifies some of the implications and potential risks and benefits these initiatives have for universities, industries and the community.

In the past half-century, American higher education has been transformed by a number of powerful social forces into a highly organized and functionally diversified enterprise composed of community colleges, teaching institutions, and research universities (Hensley and Cooper, 1992, p. 59). Hensley and Cooper (1992) claim that out of 3,300 higher-education institutions in America, about 200 are classified as research universities and although research universities continue to claim instruction as one of the three major functions (research, instruction and service), they are now dominated by research function rather than the traditional instructional efforts of most higher education institutions.

University research operations have traditionally been organized in departments. Traditionally, university-based research has been undertaken to advance basic knowledge (Betz, 1988). However, university based research has changed vastly since the Second World War in terms of size, direction, focus and the mix of activities encompassed. Four general factors have been instrumental in bringing about a significant change in university-based research system and the growth of organized research centers.

1. The dominant presence of the federal government in the post-World War II research economy which produced a research system that was heavily skewed toward programmatic research, i.e. research intended to be useful to outside sponsors (Geiger, 1992; 1993)

2. In the 1980s, a general shift in responsibility for research funding away from the federal level to the industry. Industry-sponsored research is programmatic by nature, and it has easily been the most rapidly growing component of academic research in the 1980s (Geiger, 1993).

3. A move toward multiple sponsors in financing university research. With this shift, the planning and financing of research was no longer based on a single sponsor or on single sector support (Hensley and Cooper, 1992).

4. An argument initiated by the National Science Foundation (during the 1980s) that the scientific disciplines, as organized in universities, were obstacles to the performance of research in some new and exciting areas, including those with more direct connections to applications. NSF urged a change in the university culture away from tightly bounded disciplines defined by academic departments, to a more open cross-disciplinary form of organization as exemplified by new research centers (Rosenzweig, 1992).

In 1973, an Industry/University Cooperative Research (IUCR) Program was initiated by the National Science Foundation (NSF) as a systematic attempt to discover the most effective ways to organize university research in order to stimulate industrial participation and support (Betz, 1988). As a pilot project, NSF initially funded three research centers: one at MIT, one at the University of North Carolina, and one operated under a consulting firm named MITRE which was formed mainly to act as an intermediary between universities and industries (Betz, 1988). From this experiment, Betz emphasized that two main lessons were learned:

1. An intermediary organization (like MITRE) was not needed to develop partnership between universities and industries. Having universities deal directly with industries to learn how to organize cooperative research projects proved to be the most effective approach.

2. The leadership role of the director of the research center was crucial for the success of the cooperative research program. Out of the three centers, only one (MIT) attained its goals. The MIT center director provided continuity and strong intellectual and administrative leadership in working with high-technology firms (p.301). There is also a need for the industry involved in the cooperative research program to be capable of utilizing the research for innovation.

Since 1940, when most universities were instruction dominated, over 4800 university research centers have been established in American universities, which represents a sevenfold increase in less than half a century (Hensley and Cooper, 1992, p.109). The proliferation of centers has advanced the transformation of many higher education institutions from teaching institutions to research institutions and now-a-days research center activity rivals the activity of the academic department. One of the central questions associated with this recent proliferation of separately organized research units in American universities is its impact on the management and governance of an university system.

Friedman and Friedman (1984) stressed that the fundamental problem with the organized research centers is that unlike most university departments, most of the research centers tend to lack universally agreed-upon intellectual cores and consistent nomenclature across the academic tier. They further argued that because of their idiosyncratic nature, there are no accreditation standards, no externally imposed conventions and frequently, no peers. In other words, their strength is their weakness (p. 28). A research center may command attention both because of the resources it may attract and because of the problems it may create. Potential problems include fostering extreme rivalry among departments for funds and prestige, which can be damaging to the institution; serving as power bases for ambitious faculty and administrators who are primarily interested in their own success; and not being sufficiently high in quality to add to the prestige of the university (Powers and Powers, 1988, p. 152).

Geiger (1993) also draws attention to a related development. Research units were established, he suggests, for a variety of tasks that could not be accommodated in academic departments. In keeping with the movement toward programmatic funding of research, however, the organized research units of the 1980s seem to have been predominantly intended to serve outsiders, particularly industry. Such special centers, although they seem to be quite effective for their intended purpose, are usually peripheral in location, personnel, and mission. Their proliferation has occurred largely outside the normal ties between research and graduate education (Geiger, 1993, p.75). Finally, Geiger (1993) notes that the elaboration of organized research units constitutes an organizational superstructure well removed from the university core.

The Meaning of Technology Transfer in American Universities

In the 1990s, university involvement in technology transfer has become one of the most significant trends in higher education in the United States (Smilor, Dietrich and Gibson, 1993; Matkin, 1990). Interpreting the significance of this change Matkin (1990) notes:

> College and university involvement in technology transfer is not a fad. It is producing changes in many aspects of institutions of higher education, including organizational forms of resource allocations. Most important, the increased emphasis on university technology transfer reflects a significant change in the public's view of the role of institutions of higher education and the role that such institutions accept for themselves. (p. xx)

Technology transfer activity in universities has many faces. One important aspect is establishing a visible link with the community. It is the service mission (the other being teaching and research) of universities that is coming into sharper focus and the role of universities is highlighted most prominently, where the influence and activities of university faculty and researchers are seen as playing a key role in local economic development. Traditionally, service was often viewed as a natural extension of the research and teaching role of the university. Another aspect of university technology transfer relates to provisions for the transfer of research findings from university researchers to industrial firms that result in the commercial use of the new knowledge. Implicit in this process is a greater emphasis toward research and its commercial gains. Research is clearly the prestige activity for universities and faculty members. For Matkin (1990), these changes are both exciting and threatening: exciting because they present new opportunities for universities to serve society, and threatening because, as universities move closer to the commercial world, they begin to relinquish their special place in society (p.304).

An emerging entrepreneurial university paradigm is redefining the role and scope of the university in the United States (Smilor, Dietrich and Gibson., 1993). As a result, the university's goals and ways to measure the accomplishment of those goals are being redefined and broadened. Furthermore, analyzing this paradigm shift Smilor, Dietrich and Gibson (1993) concluded that

> But this paradigm shift is also causing a tension in the university. It is raising new and important issues that have yet to be fully resolved. There is certainly the potential for conflict of interest regarding links to industry, the encouragement of faculty entrepreneurs and university equity positions in spin-off companies. Protection of intellectual property can inhibit the open exchange of ideas and information that has been a hallmark of American universities. And the increasing focus on transfer and commercialization of technology poses the potential for diminishing the role of the university as a generator of new knowledge through basic research.

> But the paradigm shift to a more entrepreneurial university appears irreversible. The real issue, therefore, becomes one of balances: of ensuring the essential contributions of the university to regional and national economies whilst preserving its integrity and autonomy. (p. 10)

The central question is: "are universities able to maintain that balance?" According to Geiger (1993) there are in fact two large ambiguities at the center of the commercial relations of universities. The first ambiguity has to do with the "economics of opportunism." Geiger(1993) further argues that no one doubts that Stanford can do these things effectively, but the question is how many other universities can emulate Stanford? Successful commercial relations depend upon the economics of opportunism, but potentially lucrative opportunities are simply not abundant at most institutions. The second ambiguity according to Geiger (1993) has to do with the rationale for engaging in commercial relationship: are they an extension of the service role of universities, or do they represent an opportunity to make money? Geiger (1993) believed that

> Universities would undoubtedly like to have it both ways, but, aside from experienced players, most cannot. Very few universities would seem to be currently turning a profit from commercial relationships. This situation is not yet really alarming, since these are often long-term investments--and they can be justified in any case as part of the service mission. But for a university truly to embrace technology transfer as part of its institutional mission requires decisive actions to assure that discoveries are disclosed, that patents are marketed, that commercial possibilities are capitalized, and that propinquity effects are realized. (p. 72)

In a report entitled *Scholarship Reconsidered*, Ernest Boyer (1990), president of the Carnegie Foundation for the Advancement of Teaching, saw the problem of redefining the missions of higher education in this way:

> The reality is that, on far too many campuses, teaching is not well rewarded, and faculty who spend too much time counseling and advising students may diminish their prospects for tenure and promotion. . . . Far too many colleges and universities are being driven not by self-defined objectives but by external imperatives of prestige. Even institutions that enroll primarily undergraduates--and have few if any resources for research--seek to imitate ranking research centers. In the process, their mission becomes blurred, standards of research are compromised, and the quality of teaching and learning is disturbingly diminished. (p. 55)

Boyer (1990) defined faculty scholarship to include four main functions - the scholarship of discovery, the scholarship of integration, the scholarship of application, and the scholarship of teaching. The "scholarship of application" recognizes the application side of knowledge and the meaning of this form of scholarship comes closer to what we currently identify as technology transfer issues. In a more recent publication, Boyer (1994) proposes a new paradigm of scholarship, one that not only promotes the scholarship of *discovering* knowledge, but also celebrates the scholarship of *integrating* knowledge, of *communicating* knowledge, and of *applying* knowledge through professional service.

American universities (particularly research universities) are experimenting with several approaches and linkages to encourage and facilitate faculty researchers to be more effective in transferring technology. Some of these emerging linkages mechanisms include joint ventures, business incubators, research parks, organized research centers, technical assistance/extension programs, research and development consortia, technology transfer centers and new types of experiential and continuing education programs. These linkages are being nurtured and developed by four types of support system within the university; business, technical, financial and educational (Smilor, Dietrich and Gibson, 1993). Business support system includes assistance with business plan development, market feasibility studies, and legal assistance on intellectual property ownership. Technical support includes consulting assistance of faculty, technical feasibility studies and access to laboratory facilities. Financial support includes equity positions in new companies, space and facilities as a form of in-kind financial assistance and allocation of endowed faculty positions to areas of applied research. Educational support encompasses continuing education for technical, professional and executive training (Smilor, Dietrich and Gibson, p.5).

Technology transfer activity in American universities has many faces. Engineering education institutions address the technology-transfer function in a number of ways. Some encourage sponsored industrial research and development contracts; others allow faculty consulting. Some establish formal technology transfer office and programs; others concentrate on their teaching and research functions. Some encourage faculty members to take their summer jobs in industry (in the U.S. generally engineering faculty members are appointed for a nine-month period); others appoint people from industry as adjunct faculty. Some arrange with industry to share equipment, facilities, and laboratories; while others organize industrial internship scheme for the students. Some provide incubator facilities in the campus; others even provide venture capital for spin-off companies. Although these initiatives involve a minority of faculty at present and are regarded as peripheral activities, they are an indication of a changing direction in the search for ways to become more economically effective.

Land-Grant Model of Technology Transfer and Its Diffusion to Developing Countries

Beal (1989) described how attempts to transfer the U.S. land-grant-university extension system to developing countries have often resulted in only limited success or in failures. Among the reasons he cited are attempts made to transfer the system with little emphasis placed on adaptation to the new environment, little efforts to analyze cross-cultural differences, and blame placed on the fledgling extension system for low productivity when there was little appropriate technology to extend.

Rivera (1991) elaborated that the land grant university extension model evolved in the late 19th and the early 20th centuries as a decentralized, largely state-funded system geared towards generating applied, locally adapted research information of interest to farmers in the state. It evolved into a pattern of linkages between producers and users of knowledge the contours of which were shaped by the local conditions including land use, farm ownership, marketing and credit management and technology of production unique to U.S. The Cooperative Extension System in the land grant movement was of particular interest to the developing countries. But the conditions necessary to establish similar linkages, both structural and with the farmers, did not exist in many developing countries when they started to import the land grant university extension system (Rivera, 1991). He highlighted that requisite forms of institutional integration and decentralization did not exist in many developing countries; and it was the lack of these conditions that resulted in limited success in the transfer of the land grant model.

Sims and Leonard (1990) argued that during the 1950s, many development experts assumed that the technology and technology transfer model (such as the land-grant model) developed in the West could be transferred unproblematically to developing countries, where it could be popularized by institutions modeled along Western lines. The experts failed to see that the two vital ingredients - an active clientele and effective site specific research - were missing in many developing countries. Sims and Leonard (1990) further noted that the institutions modeled after the land grant model in the developing countries did not respond to rural constituents' articulated demands and often misjudged their unspoken needs.

Summary

Eight central themes have emerged out of this review of technology transfer initiatives from American universities that might provide a useful perspectives for framing and organizing a coherent institutional response to technology transfer issues at institutions of higher education. These perspectives are themselves rooted in academic traditions and they focus on people who are central in any change process. To change the university one must change the feelings of the people who compose it (Matkin, 1990, p.315). Matkin further emphasized that these changes rarely can be done at a single stroke or design. Rather, such change occurs over a long period through a steady accumulation of small changes that are consistent with the direction of an increasingly accepted larger change (p.315).

1. The first of these perspectives involves the recognition that technology transfer activities from institutions of higher education can be fully effective only if they are in accord with the institution's history, organizational structure, policies, mission, and academic culture. Technology transfer activities from major research universities like MIT and Stanford are generally described as successful examples of applying knowledge to real-

life problem (Matkin, 1990., Powers and Powers, 1988., Smilor, Dietrich & Gibson, 1993., and Geiger, 1993). Not all efforts to copy the achievements of Stanford or MIT have been successful. Matkin (1990) argued that at MIT, most faculty members cited the "ambiance" of MIT as the element most encouraging to technology transfer. The generally supportive attitude of the administration and the long history of MIT's involvement with industry allowed faculty members to pursue technology transfer activities as part of their normal duties. Similarly, Matkin observes that as with MIT, Stanford's history of interaction with industry and its proximity, geographically and philosophically, to many industrial firms has created an atmosphere conducive to technology transfer (p.289). Most universities move uneasily in playing a role so visible in the community and thus subject to community scrutiny and controversy.

2. Technology transfer activities reflect the service mission of the university. Ernest L. Boyer (1994) argues that higher education institutions in America have more intellectual talent than any other institution and they should define professional service as a central mission. More than a half a century ago, the historian Oscar Handlin put the challenge this way:

> Our troubled planet can no longer afford the luxury of pursuits confined to an ivory tower. Scholarship has to prove its worth, not on its own terms, but by service to the nation and the world (quoted in Boyer, 1994, p. A48).

Models of the changing role of the university have focused on the importance of technology transfer and the changes it is causing in universities in terms of the level of resources that technology transfer activities bring to the university.

3. In any technology transfer initiatives, research and development partnership with industry tend to receive much attention. This occurs, in part, because research is generally considered a fundamental stimulus to economic development. The payoff from university-industry partnership (a form of technology transfer initiatives) tends to be slow in coming and to extend over the long term (Powers and Powers, 1988, p. 145). In this

context it is also important to review who funds research and development activities in American universities and its impact in technology transfer initiatives.

The federal government was mainly responsible for expanding the research and development activities in American universities. Table 3 indicates the university R&D system supported by federal funds (Geiger, 1992).

Table 3

Federal dependence: university R&D supported by federal funds (%)

1953	1960	1966	1976	1989
53	63	74	67	59

The federal contribution to academic R&D rose from 53 per cent in 1953, to 63 per cent in 1960, to a peak of 74 per cent in 1966; it then remained above 70 per cent for the remainder of the decade (Geiger, 1992, p. 11). In 1993, the federal contribution on research and development activities in doctorate-granting American universities was 58 per cent and the contribution by industries was 6.9 per cent (The Chronicle of Higher Education Almanac, 1993).

Lindsey (1985) reviewed research funding in the United States and concluded that the major share (about two-third) of federal support flows through the Department of Defense. However, this trend has been decreasing in the 1990s and in the year 1993, the Department of Defense spending at colleges and universities based R&D activities in the United States was $1.323 billion (about 13 per cent) out of the total federal spending of $10.014 billion (Chronicle of Higher Education Almanac, 1993).

Similarly, the *Chronicle of Higher Education* ("1995 Defense Department budget is turning into a quagmire for higher education," Scott Jaschik, July 6, 1994) reported that the House of Representative have decided to cut by half the federal government request for $1.8 billion in Pentagon support for university research. The *Chronicle* noted that the cuts were necessary because: (a) The overall Pentagon budget was so tight that no more money could be allocated for research without hurting vital military programs. (b) Too much of what universities received was being spent on overhead and not enough on actual research. At MIT, where Pentagon funds account for 18 per cent of all sponsored research, the losses due to 1995 budget cut could be more than $40.0 million (Jaschik, 1994).

4. A thrust toward increased emphasis on technology transfer initiatives from American universities is emerging (Roessner, 1989). However, programs associated with university technology transfer initiatives are generally considered as public service activities and rarely have strong alliances with teaching and fundamental research. Very few universities have a reward or compensation system to encourage faculty participation in technology transfer activities (Matkin, 1990). Matkin (1990) also described that the most difficult but also ultimately the most effective response of all is one that attempts to integrate technology transfer activities with faculty roles. While attempting to articulate a coherent institutional stance toward technology transfer, Matkin stated that

> This strategy is most appropriate where a long-term commitment to technology transfer has been made. It requires a sustained and conscious effort on a broad front in order to be successful. It involves the difficult task of changing people's feelings about technology transfer. It also requires adjustment in other traditional faculty duties, since faculty time is a "zero sum" quantity -- activities cannot be added to it without others being taken away. MIT, where faculty move freely from the academic realm to the world of business, is perhaps the best model of this integrated approach. . . . The point is that some attempt should be made to articulate a coherent institutional stance toward technology transfer. (pp. 316-317)

5. The effectiveness of technology transfer activities is difficult to measure in terms of money or of jobs gained or saved. At the same time, there is considerable pressure on the part of the universities to maintain fiscal responsibility, accountability, as well as produce measurable results from the technology transfer initiatives in order to justify continued funding. Roessner (1989) commented that this has led to a flurry of evaluation efforts by federal and state governments in the United States. He further discussed that most of the government sponsored technology transfer efforts (like the University-Industry Cooperative Research Centers Program and the Small Business Innovation Research

Program) are inevitably shaped by a combination of political and social forces. David Roessner (1989) described the importance of the political forces as follows:

> Government programs inevitably are shaped by a combination of political forces, including ideology, and empirically-based knowledge. The influence of evaluations depends on the complexity of the linkages between a program and measures of its ultimate objective, the time necessary for the objectives to be realized, and the political setting of the evaluation. In the U.S., the active role of a powerful legislature and the unique features of the innovation process together compound the uncertainty surrounding the interplay of these factors. The challenge for evaluators and program managers is to acknowledge positively the political dimension of evaluation, while ensuring that the design and implementation of evaluations properly reflect the realities of the innovation process. The challenge for decision-makers is to minimize the use of evaluations for purely political purposes. (p. 358)

6. Education and graduation of students have also been referred to as technology transfer. The 1982 report of the Joint Economic Committee of the U.S. Congress pointed out that 67 percent of high-technology companies surveyed relied on student recruiting as the most important means of technology transfer, 46 percent considered university publications important, and 42 percent valued government distribution of basic research results (quoted in Powers and Powers, 1988, p. 65).

However, Matkin (1990) categorized education and graduation of students who carry what they have learned into the commercial world, the publication of the results of research for use by the scientific and industrial community, and the consultation of faculty members by industry as *knowledge transfer* . Comparing technology transfer and knowledge transfer Matkin (1990) further stated that

> The process of knowledge transfer is considerably different from the process of technology transfer. Unlike knowledge transfer, in which knowledge is passed from the university to the receiver easily and usually with almost no follow-up, technology transfer requires considerable effort at all stages of the process. The analogy of a relay race, in which the baton is passed cleanly quickly from one runner to the other, fits most knowledge transfer situations but does not apply to technology transfer. Technology transfer might be more appropriately compared to a basketball game, in which the university is only one player. This player may bring the ball over the half-court line, but must quickly enlist the aid of teammates in order to score. In this game the "ball" is passed back and forth constantly among players who may include business people, venture capitalists, patent attorneys, production engineers, and many others in addition to university faculty. (p. 7)

7. In many successful technology transfer initiatives, entrepreneurial leaders and policy innovators played an important role as "champions' in mentoring and identifying new missions and programs for their new initiatives.

At Stanford, Vice President and Dean of Engineering Frederick Terman conceived the industrial liaison program in solid state electrical engineering in 1958 and under Terman's leadership, the liaison programs at Stanford became an important elements in the university's efforts to relate to industry and to solicit funds (Matkin, 1990). Dorfman (1983) also notes that the initiatives of Frederick Terman (who returned to Stanford after administering a World War II project at Harvard) in attracting government and business financing for his technology transfer activities is now legendary.

Similarly Bryce Jordan, who became president of Penn State University in July 1983 was instrumental in developing a successful technology transfer strategy in 1987 which gave an opportunity for the university to accelerate transfer of knowledge and technology and thereby to develop expanded dimensions of public service (Cooper and Hensley, 1992., & Matkin, 1990).

In the case of Stanford University-Silicon Valley and MIT-Route128 phenomena, Dorfman (1983) believed that the early successes of a few individual entrepreneurs powerfully influenced the direction and magnitude of regional development. Matkin (1990) also commented that Stanford's relationship to the development of Silicon Valley appears to be in large measure the result of deliberate policies and actions on the part of the university and its leaders at the time, President J. E. Wallace Sterling and Vice President Frederick Terman (p. 243).

8. University technology transfer initiatives and industry-university linkages require lengthy time frame to succeed. North Carolina's Research Triangle Park provides a case in this context.

The main concept behind Research Triangle Park was to build on a commitment to higher-education in order to establish a base for economic development (Feldmen, 1994).

The Research Triangle Park was established in 1959 (after seven years of planning) in the center of on imaginary triangle which linked the University of North Carolina at Chapel Hill, Duke University in Durham, and North Carolina State University at Raleigh (Feldmen, 1994). The main goal of this joint venture was to enhance the standing of the three universities by linking their resources. The growth of the Park was slow. In 1959 the Monsanto Company located an industrial R & D operation in the Park and for the next six years there were no other leases signed. Only in 1965, IBM became a tenant in the Park, followed by Data General, Du Pont, General Electric. By 1987, the Park had forty-seven occupants, employing 27,000 with an annual pay roll over half a billion dollars (Feldmen, 1994, p. 111). Many of the employees at the Research Park are graduates of the three universities. Highlighting the long time commitment required for such initiatives, Feldmen (1994) further articulates that:

> A commitment to the project was maintained for approximately fifteen years before the project became a commercial success. Such patience is seldom seen in the political arena that routinely demand results in two or four-year election cycles. (p. 103)

Chapter 5

ANALYSIS OF DATA I: HISTORICAL AND DESCRIPTIVE ACCOUNT OF THE INSTITUTIONAL DEVELOPMENT OF THE INDIAN INSTITUTE OF TECHNOLOGY, NEW DELHI, INDIA

Introduction

As noted earlier in chapter III, a field study was conducted at the Indian Institute of technology (IIT), New Delhi, India. All together 18 faculty members of IIT New Delhi and 2 persons involved with industries in India were interviewed. Extensive use of documentary information about IIT New Delhi was also used in the study. Most of the data were obtained by interviews. In this chapter, the analysis of the field data are presented and an attempt is made to bring the reams of collected data into manageable chunks which brings meaning and insight to the words and acts of the respondents in the study. Data analysis is the process of bringing order, structure, and meaning to the mass of collected data (Marshall and Rossman, 1989, p. 112).

The purpose of this case study is :

(1). to review the progress made by IIT Delhi in fulfillment of its broad objectives as a center of advanced studies and research in science, engineering and technology.

(2). to examine the technology transfer initiatives undertaken by the Institute and to solicit opinions from faculty members with respect to various mechanisms of transfer of technology from engineering institutions.

(3). to assess the overall impact of IIT Delhi on the training of engineers and scientists for the technological development of India.

I spent about two months in IIT Delhi to elicit opinions/views from the faculty members, students and other officials connected with the institute. Annual reports, prospectuses, bulletins, five-years development plan and IIT Delhi Alumni Association reports were used as secondary source of data.

The Development of the Indian Institutes of Technology (IIT)

A recommendation to develop a chain of technological institutions patterned after the Massachusetts Institute of Technology (MIT) of the U.S. in different industrial regions of India was made by Sarker Committee in 1945. The salient features of the plan to establish the IITs derived from the Sarker Committee Interim Report (1946) included:

1. A four year undergraduate curriculum, the first two year of which would be common to all branches of engineering and would include study in science, mathematics, humanities, and social sciences.
2. A reduction in the number of formal lectures typically required and greater emphasis on seminars, tutorials, and guided studies.
3. An examination system that would take account, internally, of work done by students throughout a term of study.
4. Flexibility in assignment of staff responsibilities to allow staff time for study and research and consultancy work in industry.
5. A scheme for workshop training and practical training in industry. (p. 18)

The selection of the MIT model was deliberate. In order to provide scientists and technologists of the highest caliber, the MIT program for engineers, based on mathematics and fundamental sciences as well as studies in humanities and social sciences, had come to be viewed as the most suitable type of technical institution to establish in India (Sebaly, 1972, pp. 3-4). The Indian planners at that time thought that if the MIT model was copied in India, its system of instruction could remedy the defects in the century-old system of training low level technical personnel to maintain equipment and oversee industrial processes imported from aboard. While reforms in technical education had been introduced and new technical institutions had been developed in India between 1898 and 1945, Indian scientists and engineers, as well as foreign observers, had made repeated criticisms of the narrow purpose of most engineering education in India, its methods of instruction and patterns of control (Preston, 1944).

The first attempt to implement the recommendations of the Sarker Committee was made in the eastern industrial region. The first IIT fully funded by the Indian government was opened at Kharagpur in 1951. While significant departures in curriculum and organization from the traditional pattern of engineering colleges in India was attempted, the first formal evaluation of the Institute's work indicated that adequate steps to implement the plan and program as envisioned by the Sarker Committee had not been taken. The reviewing committee noted that while the engineers trained by the institute had readily found employment in industry and government projects, the curricula still adhered to the traditional form of the engineering course in India (Indian Institute Technology, Kharagpur, 1959).

When the reviewing committee report of IIT Kharagpur was issued in 1960, three additional IITs were already established, and the fifth one at Delhi was in the process of being established. While each IIT was viewed as part of the chain of institutes, initiated by the Sarker Committee, and would be governed by the same IIT Act, it was expected that the program of each would reflect the industrial needs of the region in which it was located and bear the imprint of technical training model of the nation or state providing external assistance (Sebaly, 1972).

In 1958, IIT Bombay was established. It was financially supported by UNESCO from 1956 to 1966 through contributions made to the United Nations Technical Assistance Program by the former USSR.

The IIT at Madras which was opened in 1959 received assistance from the Federal Republic of Germany. The IIT at Kanpur received financial and technical assistance from the USA and opened in 1960. IIT Delhi was established in 1963 and received assistance from the UK.

The extent of each nation's assistance to equip, to provide experts for the development of a program of studies, and to train selected Indian staff abroad for service to an Institute is summarized in table 4.

Table 4
Estimate of Total Amount of Assistance of Four Nations to Establish IITs until 1970
(Sebaly, 1972).

IIT	Experts (Man Months)	Equipment	Fellowship	Total cost
Bombay	1271	$4,000,000	27	$7,200,000
Madras	1048	$4,000,000	80	$7,500,000
Kanpur	2604	$7,600,000	80	$14,500,000
Delhi	920	$2,000,000	45	$4,800,000

It is assumed for the purposes of this study that resources for the establishment of the IITs were similar except for the assistance from nations with different approaches to engineering education. The basis for this assumption is indicated by the following main features prescribed for the development and organization of the IITs.

1. The IITs have a common origin in the recommendations of the Sarker Committee made in 1946.
2. The establishment of each IIT was initiated by the same officials in the technical section of the Ministry of Education of the Government of India.
3. Government of India grants for the establishment and maintenance of the IITs are comparable.
4. The IITs are constitutionally defined as 'Institutions of National Importance,' and are incorporated under the same Parliamentary Act.
5. Admission to the IITs is made on the basis of an all-India common entrance examination drawn up by a panel of representatives of each Institute. (Chandrakant, 1963).

The Indian Institute of Technology (IIT) New Delhi

Objectives and Responsibilities of the Institute.

Beginning as a college of engineering affiliated to the Delhi University, the Institute got its IIT status in 1963 when it was declared an Institution of National Importance and was given the status of a university and the commensurate powers to decide its own academic policy, to conduct its own examination(s), and to award its own degree(s).

As an institute of national importance, it was conceived to act as a leader in technology innovation, training of the necessary manpower and to promote generally the state-of-art technology in the country. The role was to enhance the country's techno-economic strength and technological self-reliance. Initially the following two primary objectives were assigned to the institute:

(a) To offer instruction in applied science and engineering of a standard comparable to the very best anywhere in the world;

(b) To provide adequate facilities for post graduate study and research to meet the needs of specialized research workers and teachers (Indian Institute of Technology, New Delhi, 1990, p. 5).

In 1970, a committee was formed to review the working of the institute and on the recommendation of the review committee, the following additional objectives were assigned to the institute:

(c) To provide leadership in curriculum planning, laboratory development and examination system;

(d) To institute programs for faculty development both for their own staff and for teachers of other engineering colleges;

(e) To establish teaching and research programs of an interdisciplinary nature;

(f) To develop close cooperation with industry through the exchange of personnel, continuing education programs, and consultancy services to solve live industrial problems;

(g) To develop strong collaborative links with other institutions and organizations including national laboratories and government departments;

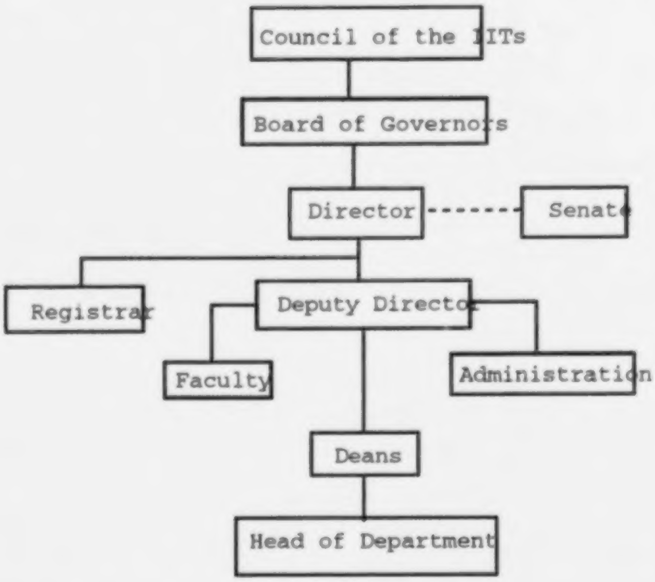
(h) To provide opportunities to the weaker sections of the society through the reservation of 22.5% of its seats for their admission to the teaching programs of the institute (Indian Institute of Technology, New Delhi, 1990, p. 6).

Governance and Management Structure

A general management structure of IIT, New Delhi is given in Figure 1.

Figure 1

Management Structure


Council of the IITs
Board of Governors
Director
Senate
Registrar
Deputy Director
Faculty
Administration
Deans
Head of Department

The original IIT Act of the Parliament of India and subsequent Statutes specify the respective roles of the council, the board of governors, the senate and the duties and responsibilities of the director.

The Board of Governors. Responsibility for the general superintendence, direction and control of the affairs of the Institute is vested in the Board of Governors. The Board functions through its standing committees- the Finance Committee and the Building & Works committee and other committees which may be appointed to consider specific issues. The Board of Governors consist of the following persons (Indian Institute of Technology, New Delhi, 1963, pp. 5-6) :

(a) Chairman-- nominated by the Visitor (The President of India);

(b) Director of IIT (ex officio);

(c) Six persons nominated by the Government who, in the opinion of the Government are technologists or industrialists of repute;

(d) Four persons having special knowledge or practical experience in respect of education, engineering or science nominated by the IIT Council; and

(e) Two professors of the Institute, nominated by the Senate.

The functions of the Board of Governors as per the provision of the IIT Act is as follows:

(1) take decisions on the questions of policy relating to the administration and the working of the Institute;

(2) institute courses of study at the Institute;

(3) make statutes;

(4) institute and appoint persons to academic as well as other posts in the Institute;

(5) consider and modify or cancel ordinances;

(6) consider and pass resolutions on the annual report, the annual accounts and the budget estimates of the Institute of the next financial year and submit them to the council together with a statement of its own development plan;

(7) exercise such other powers and perform such other duties as may be conferred or imposed upon it by the Act or the Statutes.

The Senate. The Senate decides the academic policy the Institute. It controls and approves the curriculum, courses and examination results. The composition of the Senate is as follows :

(a) Director of the IIT--Chairman (ex officio);

(b) Deputy Directors (ex officio);

(c) All professors;

(d) Heads of departments, centers and divisions other than professors;

(e) Librarian;

(f) Workshop superintendent;

(g) Three persons, not being employees of the Institute, to be nominated by the Chairman of the Board in consultation with the Director, from among educationists of repute, each from the fields of science, engineering and humanities;

(h) Not more than six other members of the staff for their special knowledge appointed by the Chairman of the Board after consultation with the Director for such period as may be specified by the Chairman of the Board of Governors.

Some of the important functions of the Senate are :

(1) to frame and revise curricula and syllabi for the courses of studies for the various departments;

(2) to make recommendations to the Board of Governors regarding conferment or grant of degrees, diplomas and other academic distinctions or titles;

(3) to appoint advisory committees or expert committees for the department of the Institute to make recommendation on academic matters connected with the working of the department. The head of the concerned department will act as convener of such committee;

(4) to make recommendations to the Board of Governors with regard to (i) the creation of posts on the academic staff and the abolition thereof, and (ii) the emoluments and duties attached to such posts;

(5) to promote research within the Institute and require reports on such research from the persons engaged thereon.

The IIT Act provides that the Senate will have the powers of institutional control and general regulation and be responsible, for the maintenance of standards of instruction, education and examination in the Institute. The Senate must periodically review the academic activities of each department in depth and take a definite view on the efficacy of the department. The successes and failures of each department, its strengths and weaknesses should be discussed in the Senate and their findings and specific suggestions should be regularly available to both the Board of Governors and the concerned department. The Senate as the highest academic decision making body should be responsible to constantly watch that excellence is achieved in each departments, centers and divisions.

The Director and the Academic Team. The IIT Act provides that the Director of the IIT should be appointed by the council of IITs with the prior approval of the Visitor. The Council has evolved its own procedure for the appointment of a search committee who after contacting a number of people suggest a certain name in respect of whom, a prior approval of the visitor is obtained. The Council of IITs then appoint such a person as the Director. The Act declares that the Director is the principal academic and executive officer of the Institute and is responsible for the proper administration of the IIT and for imparting of instruction and maintenance of discipline therein. The Director also acts as the chairman of the Senate. With respect to academic administration, the Director at IIT Delhi is assisted by two deputy directors (one for faculty and the other for general administration), and five Deans (undergraduate studies, postgraduate studies and research, students affair, industrial research and development and administration).

The IIT Act and Statutes delegates very little power to the Director. Most of the powers are vested with the Board of Governors. As an example the Director does not have the power to send members of the staff for training aboard. The Director has to get the authorization of the government to send any staff of IIT to attend a conference aboard even if there are no costs incurred to the IIT system. Some of the duties of the Director as mentioned in the IIT Act and Statutes are as follows :

(1) The Director shall have the power to send members of the staff for training or for a course of instruction inside India subject to such terms and conditions as may be laid down by the Board of Governors from time to time.

(2) The Director shall have the power to re appropriate funds with respect to different items constituting the recurring budget up to a limit of Rs. 10,000 (about $350) for each item, provided that such re appropriation will not involve any liability in future years. Every such re appropriation shall, as soon as possible, be reported to the Board of Governors.

(3) In exceptional cases, subject to availability of funds, the Director shall have the power to create temporary posts with the approval of the Chairman of the Board of Governors, of not more than two years' duration on approved scales of pay under report to the Board provided that no such post, of which the Director is not the appointing authority, shall be so created.

(4) The Director shall have the power to fix, on the recommendations of the selection committee, the initial pay of an incumbent at a stage higher than the minimum of the scale, but not involving more than five increments, in respect of posts to which appointment can be made by him under the powers vested in him by the provisions of the Act (Indian Institute of Technology, New Delhi, 1963, pp. 30-31).

Issues and Challenges

During the interviews with faculty members, the respondents outlined various administrative obstacles and hindrances that acted as road blocks on the way to an efficient functioning of the Institute. Some important issues and challenges as articulated by majority of the respondents are presented as follows:

* The composition and functioning of the Board and its relation to and cooperation with the Senate and the Director, the leadership provided by it and its ability to utilize power vested in it are very crucial for the success of an IIT system.

* The institute is bound by many rules and regulations. There is minimal academic and operational autonomy.

* The present composition of the Senate does not have any representations from the administrative staff and from the students. As the Senate considers and decides matters which are directly related to their interests, the Senate should have representations from the administrative staff and students.

* The leadership role (technology transfer and entrepreneurial) of the Director is crucial for any effective technology transfer efforts from engineering education institutions like the IITs.

Most of the respondents indicated that the organizational structures at the Institute are notably slow to move. They also felt that opportunities to create a participatory decision making environment, which they regarded as necessary to the success of the Institute, were missing. One of the important components that would make technology transfer initiatives successful, according to the respondents, was the establishment of a decentralized management and governance structure at the Institute. In this context, one faculty member indicated:

> Technology transfer initiatives require commitment at all level of the organization. There must be larger number of people participating in managing the Institute rather than a sole authority issuing orders.

Academic Departments/Centers.

The academic work of the IIT is transacted through departments and centers. At present the Institute have the following 12 Departments and 9 Centers:

Departments: (a) Applied Mechanics (b) Chemical Engineering
(c) Chemistry (d) Civil Engineering (e) Electrical Engineering

(f) Humanities and Social Sciences (g) Mathematics

(h) Mechanical Engineering (i) Physics (j) Textile Technology

(k) Computer Science and Engineering (l) Management Studies

Centers: (a) Center for Applied Research in Electronics (CARE)

(b) Center for Atmospheric Sciences

(c) Biochemical Engineering Research Center

(d) Center for Biomedical Engineering (e) Center of Energy Studies

(f) Center of Industrial Tribology, Machine Dynamics & Maintenance Engineering (g) Instrument Design Development Center (h) Center for Material Science & Technology (i) Center for Rural Development & Technology.

The IIT Statutes provide that:

1. Each Department of the Institute shall be placed incharge of a Head who shall be appointed by the Director from amongst the Professors, Associate Professors and Assistant Professors. Provided that when in the opinion of the Director the situation so demands, the Director may himself take temporary charge of a Department or place it under the charge of the Deputy Director or a Professor from another Department for a period not exceeding six months.
2. The Head of a Department shall be responsible for the entire working of the Department, subject to the general control of the Director.
3. It shall be the duty of the Head of Department to see that the decisions of the authorities of the Institute and of the Director are faithfully carried out. He shall perform such other duties as may be assigned to him by the Director (Indian Institute of Technology, New Delhi, 1963, p. 49).

Similar terms of reference are also followed with respect to the Head of the Center. Generally the Head of Department is offered automatically to a Professor on the principle of rotation. Some faculty members pointed out that the Head of Department should be an elected post and not offered automatically to a Professor on the principle of rotation and seniority. They were of the opinion that good management skill should be one of the important criteria for selecting a Head of Department. Academic ability of a faculty member or just being a senior professor is by no means an adequate criterion for good management, which is what the Head of a Department is essentially required to ensure.

> Although educational plans and policies emphasized the need for a decentralized form of management, most of the respondents outlined that no significant efforts at decentralization of administrative duties and delegation of powers, accountability and responsibilities were made at the operational level be it in the departments, centers or at the offices of the deans or the director. They all noted that there is an urgent need to inject greater autonomy in the normal functioning of the department.

Research centers. In addition to academic departments, IIT Delhi has 9 research centers. Research Centers were established to promote initially, inter-disciplinary research by linking research efforts in various departments and by linking similar activities in other technical institutions in the country (Indian Institute of Technology, 1986). They were started as nodal points to foster research and become peak points in some selected areas of importance, generally inter-disciplinary in character, drawing talent from the departments and outside research organizations. Assessing the contributions of research centers, a faculty member stated:

> In the Fifth Five Year Plan (1974-79) the Government of India, suggested establishment of research centers of advanced studies in the IITs which could initiate intensive time bound R&D effort in some of the critical areas as identified in the Science and Technology Plan. In 1976, a committee headed by Prof. Nayudamma recommended the establishment of only one research center in each IIT during the Fifth Five Year Plan. This center of advanced R&D activities in the IIT was conceived by the Nayudamma Committee as a peak point for research activities serving the whole nation. These were not set up as rivals to the departmental activities but to complement and enhance their inter-disciplinary functions. These centers were conceived to act as centers of excellence for advancing frontiers of science and give the country a break-through in technology. These principles under which research centers should be established is still very valid to-day. Unfortunately at IIT Delhi, the principles and objectives as stipulated by the Nayudamma Committee have been to a certain extent breached. Centers have proliferated but there is very little collaboration and cooperation between a department and a research center. In some cases

> centers have started awarding Ph.D. degrees and in most of the cases have functioned in isolation with very little input from the established departments. Centers thus became the rival sources of claim on resources and power and the specific role assigned to the centers in the Plan document (1974-79) appears to have been completely forgotten. I have to mention that some centers have done remarkably well, some of them are engaged in innovative research and developmental works, but the majority of the research centers have only done peripheral research work. I feel that the entire question of the functions and the achievement of the centers needs to be reviewed critically to ensure proper focus and character. The tendency for centers to function like any other academic departments has to be curbed.

Academic Programs

The Institute offers a wide range of academic programs both at the undergraduate and postgraduate levels. At the undergraduate level, it offers a 4-year program leading to the Degree of Bachelor of Technology (B.Tech) in Chemical Engineering, Computer Science and Engineering, Electrical Engineering, Mechanical Engineering, Manufacturing Science and Engineering, and Textile Engineering. It also offers a 5-year integrated M.Sc program in Mathematics and Computer Applications, and a 5-year integrated M.Tech program in Biochemical Engineering and Biotechnology.

At the postgraduate level, the Institute offers 3-semester (1.5 years) programs leading to the degree of Master of Technology (M.Tech) in various specialization. The Institute also offers a 2-year Master of Science (M.Sc) program in Physics, Chemistry and Mathematics. A significant feature of the postgraduate program is the opportunities they offer to in-service engineers and scientists for part-time study through modular and evening programs. Most of the departments and centers also offer Ph.D. programs.

IIT New Delhi is a fully residential campus which extends over an area of about 320 acres. About 2800 students and 520 academic staff and 1900 administrative and support staff live in the campus.

Admission to the undergraduate programs and the integrated M.Tech and M.Sc programs is made through a All-India Joint Entrance Examination (JEE), common for all the five IITs. The JEE is well known for its fairness and is popular among grade 12 students. Approximately about 80,000 students appear every year for the JEE for about 1500 placements at the five IITs. Examination takes place for two days in four subjects namely Chemistry, Physics, Mathematics and English. Admission to the IIT depends exclusively on one's rank in the JEE merit list. Admission to the M.Tech program is also made through an All India Entrance Examination called GATE (Graduate Aptitude Test in Engineering).

The student population for the academic year 1992 at IIT Delhi was: (Indian Institute of Technology, New Delhi, 1992)

* Undergraduate (B.Tech.)-------------------------------- 1177
* Postgraduate (M.Tech. and M.Sc.)--------------------- 1186
* Ph.D. -- 731

Total 3094

Similarly in the academic year 1991-92, 829 candidates graduated from IIT Delhi. The details are as under :

* B.Tech. --- 239
* M.Tech. --- 397
* Postgraduate Diploma ----------------------------------- 21
* M.Sc --- 55
* Ph.D. -- 117

The numbers of students who have graduated from the Institute from 1963 till 1990 are indicated below : (Eight Five Year Plan, IIT Delhi, 1990)

* B.Tech.-- 5300
* M.Tech. --- 3458
* M.Sc. -- 741
* Postgraduate Diploma----------------------------------- 382
* Ph.D. -- 1312

Placement Of IIT Graduates

In 1984 a high level committee under the chairmanship of Prof. Y. Nayudamma was set up to review the progress of the IITs in fulfillment of its board objectives as a center of advanced studies and research in science, engineering and technology. One of the objectives of the Nayudamma Committee was also to assess the overall impact of the IITs on the training of high grade engineers for the technological development of India. One of the areas of concern of the Committee was that there was no reliable data available at that time regarding the placement of IIT graduates. Accordingly, in 1985, the Review Committee requested the Association of Indian Universities to carry out a quantitative and qualitative study of the employment patterns of IIT graduates in India and aboard. A study with the following objectives was carried out in 1985 by the Association of Indian Universities :

(a) to study the placement of B.Tech. graduates of the five IITs in India and aboard

(b) to seek the opinion of IIT graduates through a sample survey with questionnaires, regarding,

  (i). relevance of IIT curriculum to their job requirements in India

  (ii). the level of satisfaction of the graduates in the Indian job market

(c) to suggest

  (i). changes in curriculum of IITs so as to make it more relevant to present needs of the industry, and

  (ii). other changes in the IIT system for better utilization of its graduates by industry in India.

Approximately 6000 questionnaires were administered to B.Tech. graduates working in India and aboard. The selection of graduates was made at random from four blocks of years 1957-60, 1966-69, 1972-76 and 1979-82. Data of 2416 B.Tech. graduates were received. In the study care was also taken to take samples from each discipline within each IIT and from each sector of employment. The major findings of the study are indicated below (Association of Indian Universities, 1985):

Placement:

1 Abroad

(1) On a average about 20% of the B.Tech. graduates leave India to work aboard. Out of this about 23 per cent of the graduates abroad are engaged in research and development works. This proportion is nearly twice of those employed in R & D work in India. Teaching has attracted about 13 per cent of the graduates employed aboard.

(2) The majority of IIT graduates aboard are employed in the private sector, multinationals being the main employers.

(3) In the public sector, universities are the major employers of IIT graduates.

(4) The majority of B.Tech. graduates working aboard have indicated that they have excellent opportunities to:

  (a) achieve their academic and professional growth:

  (b) get recognition of hard work and educational and professional competency;

  (c) experiment and apply knowledge in practice;

  (d) work in their own area of specialization.

(5) The proportion of IIT graduates employed aboard in production and maintenance (14 per cent) and marketing (7 per cent) is much less as compared to those graduates employed in India. The corresponding proportion of IIT graduates employed in India in the area of production and maintenance is 31 per cent and in marketing is 14 per cent.

(6) The per cent distribution by professions of B. Tech. graduates of IIT Delhi working aboard are:

  * Teaching -- 6 per cent * R & D -- 12 per cent

  * Production and maintenance -- 16 per cent * Consultancy -- 14 per cent

* Project planning & design -- 22 per cent * Marketing -- 16 per cent

* Management -- 8 per cent * Non-respondents -- 6 per cent.

2. India

(1) Data indicated that IIT graduates employed in private and public sectors in India were about equal in number.

(2) About 62 per cent of the graduates of IIT Madras found jobs in the public sector (Government departments, universities & public limited companies). Whereas 58 per cent of the graduates of IIT Bombay joined the private sector (Multinational companies, private industry, firm). The graduates from the other IITs conform to the general pattern. This reflects the influence of the industrial environment where the IIT is located (Association of Indian Universities, 1985).

(3) Nearly 46 per cent of the IIT graduates were working in the professions of production and maintenance, research and development, and teaching, thus directly contributing to industrial and technological development of India. About 28 per cent were working in the areas of consultancy and project planning and appraisal. Whereas about 25 per cent of IIT graduates moved over to management and marketing.

Analysis of the placement pattern of IIT graduates, who graduated in different blocks of years (1957-60, 1966-69, 1972-76 & 1979-82) by types of employers and by professions revealed that employment in R & D showed an increasing trend in India and abroad during 70s and 80s. On the other hand the proportion of IIT graduates employed in manufacturing, production and maintenance has shown a declining trend during the last two decades in India as well as abroad.

In the Nayudamma Review Committee Report-1986 it was highlighted that the majority of the IIT graduates who stayed in India engage themselves in managerial jobs and not in engineering professions or in R & D sector for which they were trained. The Report did not provide any evidence to support their conclusions. However, the report on placement of IIT graduates conducted by The Association of Indian Universities in 1985 did not find any definite trend regarding placement of IIT graduates in managerial jobs. They indicated that the area of marketing was an attractive profession over the years (70s & 80s) and the share of B.Tech. graduates showed an increasing trend till 1972-76. Whereas the trend somewhat reversed for the batches which graduated during 1979-82 (Association of Indian Universities, 1985).

Relevance of IIT Curriculum. The Association of Indian Universities' report (1985) on the placement of IIT graduates also dealt with the issue regarding the relevance of IIT curriculum to job requirements in India. They presented the following findings:

(a) 33 per cent of the B.Tech. graduates employed in India had indicated that their courses had very little relevance or total irrelevance with their respective jobs.

(b) 43 per cent of the graduates in the categories of entrepreneurs, executives and employees of multinational companies did not find the IIT academic program relevant to their job.

(c) The responses of the IIT graduates who graduated during different blocks of time (1957-1982) indicate that the relevance of their courses to their professions has decreased over the years. 20 per cent of the graduates who graduated during the year 1957-60 indicated total lack of relevance of their courses to their professions. This proportion increased to about 28, 38 and 40 per cent for the batches graduated during 1966-69, 1972-76 and 1979-82 respectively. The 1985 Report clearly mentioned that this trend was very alarming and was significant.

Working Conditions. On the issue of work conditions and satisfaction the Association of Indian Universities 1985 Report revealed the following findings:

(a) Generally, more than the financial benefits, the lack of opportunities to work in one's own area of specialization and application of knowledge in practice, are the most important causes of dissatisfaction of the B.Tech. graduates working in India.

(b) However about 63% of those in the teaching profession seem to be dissatisfied on account of inadequate financial benefits.

(c) Most of the graduates working with the government seem to be dissatisfied on all accounts, i.e. financial and work opportunities.

(d) Majority of the IIT graduates working abroad indicated that they had excellent opportunities to achieve their academic and professional growth, to get recognition of hard work and educational and professional competency, to experiment and apply knowledge in practice and to work in their own area of specialization.

Another important study which was carried out to investigate the role and impact of IIT graduates (particularly graduates from IIT Delhi) was also done in 1985 by the Alumni Association of IIT Delhi. The main objectives of the study was to highlight the role of IIT Delhi B.Tech. graduates in India's economy and the usefulness (or otherwise) of the time spent at IIT Delhi. They analyzed the profile of B.Tech. graduates who graduated from IIT Delhi from 1966 to 1979. During that period (1966-1979) about 2886 had graduated from IIT Delhi, out of which the Association was able to process information on 1183 B.Tech. graduates, which constituted about 40% of the total population. During their research the Alumni Association also solicited written responses from senior alumni who were grouped in four categories namely -- alumni who stayed on in the technical line, those who went abroad and stayed on, those who moved into non-technical fields and those who started their own industry. Nearly sixty responses were received and analyzed. Their analysis indicated the following findings: (Indian Institute of Technology, Alumni Association, New Delhi, 1985)

(a) Only about 29% of the graduates remain in the technical line. This finding substantiated the feeling expressed in many forums that a large proportion of the graduates from the IITs do not go into technical fields.

(b) About 3.7% of the graduates went into teaching.

(c) Nearly 30% of the graduates entered to management fields. Out of that only about 4% entered the public sector in management fields. All the rest opted to enter the private sector.

(d) About 9% of the graduates settled abroad.

(e) The government sector attracted about 18% of the graduates, out of which the largest proportion were civil engineering graduates where as many as 44% entered the government services.

(f) Nearly 12% could be classified as entrepreneurs, who did start their own business or small scale industry.

In analyzing the responses received from IIT Delhi alumni, the report also indicated that the responses had a common theme running through them- IIT education should have greater exposure to the practical world. Many of the recommendations from the alumni centered around two major ideas - (a) gaining more practical knowledge and (b) exposure to more business and management oriented courses. One common theme that emerged from the responses was that the standard of teaching has been of an exceptionally high order. The majority of them believed that a graduate who comes out from the IIT system had adequate capability to take up the task in any organization or industry. Some of the respondents noted that there was no champion or role model figure in IIT Delhi. They were of the opinion that visionary leaders were essential for an IIT system not to be deterred from its quest for excellence at any cost.

An interesting comment from that study was that no written responses were received from alumni who had joined the faculty of IIT Delhi. It implies that either they have nothing to contribute or are afraid or unwilling to make comments. (Indian Institute of Technology, Alumni Association, New Delhi, 1985, pp.3)

Perceptions of IIT education

Comments and reactions of all the respondents who were former graduates of an IIT system (about 20 per cent of the faculty at IIT New Delhi were IIT graduates) confirmed that the IITs which were specifically set up as institutes of national importance, have set up high standards of engineering education. There was a general consensus that the course structure in engineering program was excellent. They also indicated that the engineering fundamentals learnt at IITs were very useful. Most of them agreed that the IIT education and the residential campus social life provided them with a solid background for future growth. One of the respondents stated:

> My IIT education at Bombay in the 60s was extremely helpful in understanding any industrial process, product and technical problems that go with it. In general an IIT education makes an individual analytical, logical and more confident of handling any situation.

Some of the respondents also identified various strengths and weaknesses of an IIT education. They saw the strengths of the engineering education programs in terms of broad-based engineering knowledge, flexibility of the syllabus and significant content of humanities and social sciences in the curriculum. Similarly, an emphasis on industrial training during the final year was also viewed as a positive step in producing an all-round engineers. On the other hand, the respondents also identified certain areas of weaknesses of the IIT education. Among them were the lack of industry-institute collaboration, inadequate resource support for laboratories and workshop, lack of marketing, financial and other management courses, inadequate emphasis on entrepreneuring skills and lack of exposure to the practical world. In this context, one of the respondents stated:

> IIT education does not prepare you to be an entrepreneur. The teaching approach is still too theoretical. One could not relate to the real life applications in many courses. The curriculum should include more courses in management, social sciences, marketing and finance. The students should have enough entrepreneuring skills developed so that by the time they come out of an IIT system, they are well versed with running on their

own a small or medium scale business or industry. Generally IIT graduates who have started their own business or industry after graduation had family business connections. In India this business family background has an important bearing on one's decision to run one's own enterprise.

Research and Development

IIT Delhi has now completed 30 years of its existence. During the initial phase (1963-1973), the Institute developed the undergraduate programs of study and set up of laboratories and other facilities for research under postgraduate level academic programs. The next phase (1974-1984) of the development was devoted to consolidation and strengthening of those academic programs. As a result of these developmental activities, the Institute has acquired considerable research facilities in various departments and centers; both in terms of physical facilities and highly capable science and engineering faculty. In 1991-92, IIT Delhi had an academic staff strength of about 520 of whom about 90 per cent had Ph.Ds. They are distributed among 12 departments and 9 centers. Most engineering and technological institutions in India suffer from inadequate numbers of highly qualified faculty (Chandrakant, 1976). IIT Delhi, however, is more fortunate in this respect.

In 1976, in order to strengthen research and developmental activities, an Industrial Research and Development (IRD) Unit was established at IIT Delhi. The main objectives for the Unit was to :

(a) provide consultancy services to the industry on their live problems;

(b) organize in-service short term courses to cater to the specific needs of the industries;

(c) transfer the inventions/new processes and design evolved at the Institute for commercial exploitation by the industry, and

(d) process, secure and administer sponsored research projects from industries and other research institutions (Indian Institute of Technology, New Delhi, 1990).

Research activities pursued by IIT Delhi could be classified into two categories namely :

(1) Sponsored research projects

(2) Consultancy assignments

Sponsored research projects occupy an important role in financing research and development activities at IIT Delhi. Usually the sponsoring agencies for research projects are Government departments such as Department of Electronics, Department of Science and Technology, Department of Defense Research, etc. Very few research projects are sponsored by industries (both public or private). Consultancy assignments are generally sponsored by the industry. Fig.(2) and Fig.(3) indicate the number and amount of sponsored research projects and consultancy assignments at IIT Delhi from 1985 till March 1993.

At IIT Delhi, funding from outside agencies for undertaking research and development activities started only in 1976 with a modest financial outlay of Rs.150,000. In 1992-93, the total funds committed for R & D activities (both sponsored research projects and consultancy jobs) was about Rs.43.8 millions. The most impressive year was 1991-92, where the total funds committed for research work was about Rs.63.6 millions. From the data it is evident that research activities in terms of number of research projects and the amount of funds committed has not been expanding at the Institute in the last decade.

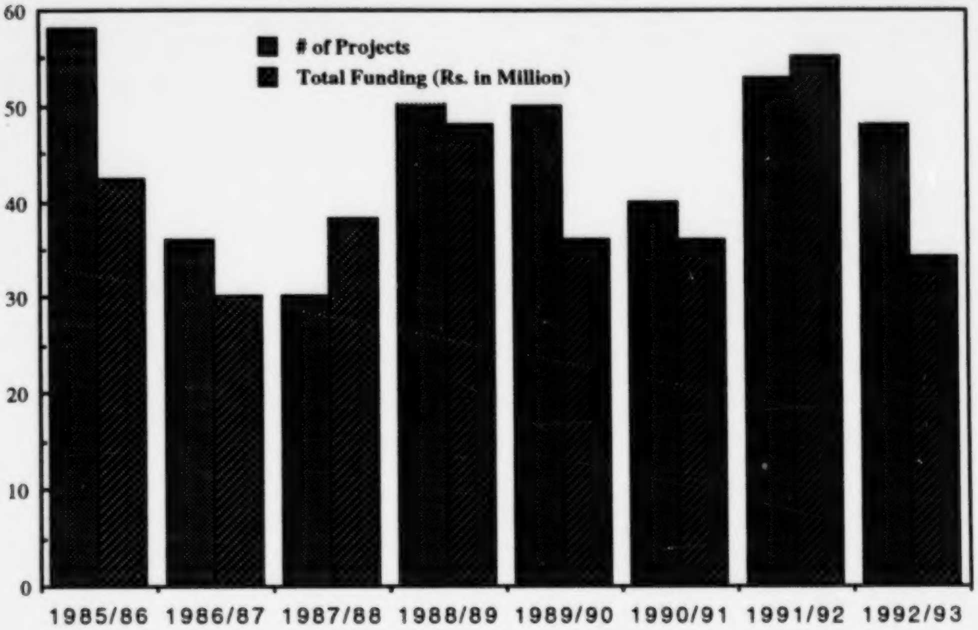


Figure 2: Pattern of Sponsored Research Projects at IIT New Delhi
(Cumulative of all Departments and Centres)

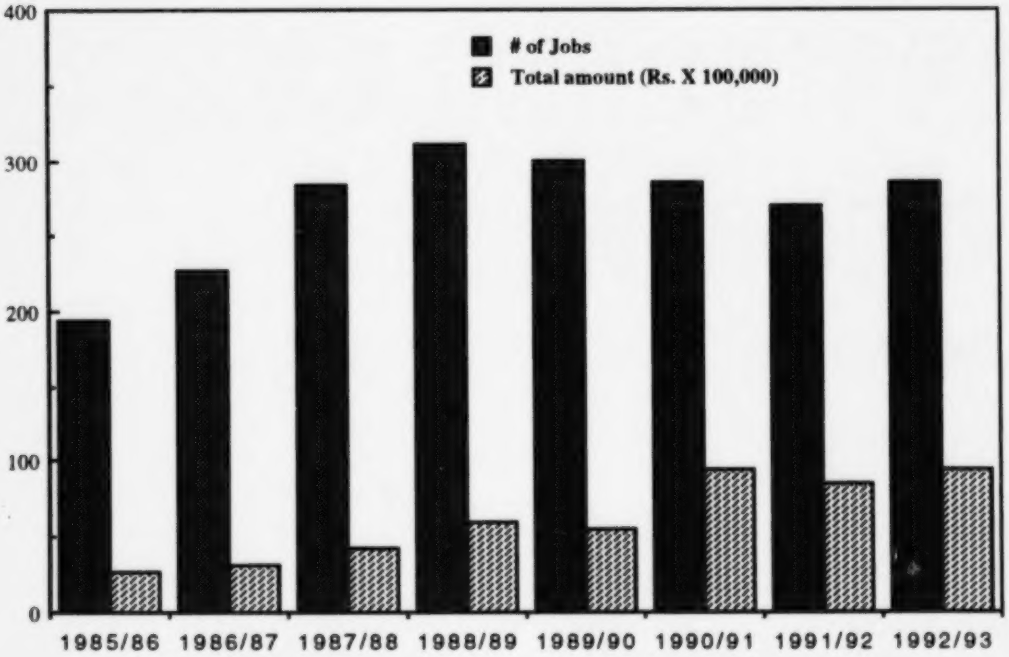


Figure 3: Pattern of Consultancy Jobs at IIT New Delhi
(Cumulative of all Departments and Centres)

The 1986 Prof. Nayudamma Review Committee Report also indicated that the research works pursued by the IITs did not have an effective imprint on the Indian national scene. While dealing on the issues and problems of sponsored research projects for the IIT system as a whole, the Report stated :

> The IITs currently obtain Plan assistance from several government departments who sponsor specific projects with the IITs. While such sponsorship has been of help to them it has also left behind problems with the IITs. Usually a sponsoring authority identifies a Project Investigator in the IIT, who develops a project, works out the cost and finalizes project details. The plan assistance received from government departments is based on the assumption that necessary infrastructure is available in the IIT and it is profitable for the funding agency to utilize existing resources in an IIT instead of investing on their own. In actual practice the sponsored project forces IIT to recruit more personnel such as scientific staff, technical personnel, workshop and non-faculty staff whose appointments are made out of the project funds and to be terminated at the end of the project. When project authorities cease to fund the project at the completion of the task, the IIT concerned is on the look-out for similar projects, where staff already recruited can be further employed, thus transferring the liability of further employment of these personnel on a project-to-project basis.... Hopes are thus built that by such a process they are being permanently absorbed as employees of the IIT.... No IIT can afford to absorb such a large number of staff as institution staff.(Indian Institute of Technology, 1986, pp. 30)

The distribution of number of research projects, funds committed and the number of consultancy assignments among the various departments and centers are skewed. Table 5. indicates the patterns of funding in sponsored research projects for a five years periods (1985 to 1990) for the different departments. From table 5. it is evident that Rs. 78.1 millions was available during the five years period (1985-1990) in sponsored research projects for the different departments. Out of this total, the share of the department of physics accounted for about 57 per cent (Rs. 45 millions), whereas, the share of the department of computer science and engineering was only about 3 per cent.

Table 5

Funding patterns of sponsored research projects (1985-1990) for different departments

Departments	Total funds (1985-90) Rs x 100,000	Number of Projects	Staff salary Rs x 100,000	Equipment Rs x 100,000
Chemical Engineering	68.52	14	24.28	34.65
Chemistry	49.27	13	12.39	29.75
Civil Engineering	60.26	10	22.53	23.07
Computer science & Engineering	24.97	4	7.18	15.29
Mechanical Engineering	76.08	7	18.12	49.12
Physics	450.21	33	83.90	317.63
Electrical Engineering	52.43	11	15.18	11.71

(Source: Eight Five Year Plan 1990-1995, IIT New Delhi, complied by author)

Similarly the pattern of sponsored research funding for the research centers also presents a very skewed distribution. Two research centers (applied electronics and biomedical research centers) accounted for about 73 per cent of a total sponsored funding of about Rs. 81.7 millions in the five years period (1985-1990). All the funds for sponsored research projects came from the government departments.

Table 6

Funding patterns of sponsored research projects (1985-1990) for different research centers

Centers	Total funds (1985-90) Rs x 100,000	Number of Projects	Staff salary Rs x 100,000	Equipment Rs x 100,000
Applied research in electronics	402.07	13	66.92	252.82
Atmospheric sciences	57.39	15	20.25	22.55
Biomedical engineering	220.02	14	54.38	111.54
Energy studies	72.11	17	32.15	29.47
Material science and technology	72.78	11	16.29	46.60
Rural development and technology	32.91	12	20.18	4.27
Systems and management studies	1.05	2	0.70	0.00
Biochemical engineering	31.89	2	1.35	27.20

(Source: Eight Five Year Plan 1990-1995, IIT New Delhi, complied by the author)

Similarly in the case of consultancy jobs, the distribution of funding is also very skewed for the departments and the research centers. Table 7 presents the funding pattern of consultancy jobs for the different departments. The total funds (1985-1990) available for consultancy jobs for the different departments amounted to about Rs.12.6millions, out of which the department of civil engineering and the department of applied mechanics had a large share of about 40 per cent and about 20 per cent respectively.

Table 7

Pattern of funding of consultancy jobs for different departments (1985-90)

Departments	Total funds (1985-90) Rs x 100,000	Number of Jobs	Fee Rs x 100,000	Expenses Rs x 100,000
Chemical Engineering	7.62	63	3.97	3.64
Chemistry	2.26	28	0.98	1.28
Civil Engineering	51.27	382	38.62	12.66
Applied Mechanics	26.38	263	15.95	10.43
Mechanical Engineering	17.31	90	9.15	8.17
Physics	10.88	55	2.34	8.54
Electrical Engineering	11.07	58	4.70	6.37

(Source: Eight Five Year Plan 1990-1995, IIT New Delhi, complied by the author)

Table 8 indicates the funding pattern of consultancy jobs for the various research centers.

Table 8

Pattern of funding of consultancy jobs for different centers (1985-90)

Centers	Total funds (1985-90) Rs x 100,000	Number of Jobs	Fee Rs x 100,000	Expenses Rs x 100,000
Applied research in electronics	6.53	17	4.29	3.37
Atmospheric sciences	6.00	4	0.85	3.87
Biomedical engineering	4.22	28	54.38	111.54

Energy studies	11.13	21	6.58	4.55
Material science and technology	3.98	30	1.81	2.16
Rural development and technology	0.75	1	0.07	0.68
Instrument Design Development	10.05	40	5.22	4.84
ITMME*	13.33	91	8.31	5.02

(Source: Eight Five Year Plan 1990-1995, IIT New Delhi, complied by the author)

* Industrial Tribology, Machine Dynamics & Maintenance Engineering

The Institute has, over the years, made conscious efforts to develop and nurture international collaboration in research with leading foreign university with a view to securing mutual growth in areas of high technology. Some of the facets of these collaborations included faculty exchange, joint research and fellowships training for IIT faculty at the post-doctoral level. Most of the collaborative research projects are with the universities in U.K. In the year 1991-92, there were two ongoing collaborative research projects in the field of sonar technology and instrumentation technology with University of Technology, Loughborough, two projects in the area of railway vehicle suspension system and erosive wear with Thames Polytechnique and one research project each with Cambridge University (solid mechanics), Imperial College (applied mechanics), University of Sussex (microprocessor application), University of Stathclyde (fiber optics and optical communication) and University of Reading (atmospheric sciences). In addition, some collaborative research projects were also initiated with research institutions in France, Japan, Federal Republic of Germany and Former USSR.

The Role of Research and Development

Most of the respondents indicated that an Institution of National Importance like an IIT should have a visible link and cooperation with the economy and the society at large. They observed that the calls for greater IIT involvement in the economy have come at a time when the IITs are facing major problems of their own. These include cuts in government grant, accessibility, autonomy, maintenance of standards, financing of research, upgrading of facilities and equipment and an aging professoriate. While stating that "students coming out of IIT are of an extremely high intellectual caliber" they highlighted that the students need to be specifically groomed to meet the challenges of Indian industry and the community at large. They wanted the Institute to adopt a more aggressive stance in developing interface opportunities and arrangements with industry and initiate various technology transfer mechanisms. One of the respondents observed:

> Interaction between the Institute and industries is currently being achieved mainly through provisions of consultancy services. Sponsored research projects are generally awarded from government departments. The problems at IIT Delhi are currently tied to some extent to the financial cuts imposed by the central government. However, I believe that the problems will not be solved simply by increased funding. The solution lies in strategic planning and management of IIT activities in order to make the Institute more efficient and more effective. We have to be willing to go beyond the status quo, to search for a new understanding of the position and roles we can play in changing Indian socioeconomic milieu. In this context IIT-Industry linkages is the key. IIT as an institution is an under-utilized resource which could assume an expanded role in stimulating the economy. We should emphasize the promotion of economic development and technology transfer as a major theme of the IIT's mission. Value should be attached not only to knowledge for its own sake but also to knowledge applied to solve the problems of society.

This indicates the genuine interest of many faculty members in having their work directly related to the needs of the society. However, the majority of the respondents noted that a clear expression of concern regarding the role and impact of research and development activities at the IITs is still missing. They complained that no study has been conducted on the rationalization of R&D activities at the IITs. One of the faculty member observed that a public declaration in the form of a policy statement that is seen to reflect faculty consensus and concerns regarding the economic and technology transfer role of the institute is essential in order to manage and promote technology transfer partnership. Many faculty members indicated that public declarations on important issues that reflect faculty consensus is bound to influence attitudes within the institute, especially since these policies may promote and stimulate action. Commenting on the lack of research and development links with the industry, one of the respondents stated:

> At IIT Delhi there is a lot of rhetoric going on about IIT-Industry linkages. At present we do not have any healthy cross flow between industry and the IITs. There is an urgent need for IITs to take an initiative in this matter. In this context the Government and the industries should also come out with innovative policy vis-a-vis engineering research and the role of engineering institutions. Currently, in India industries are able to import turnkey projects. Such turnkey solutions prevent institutions like IITs to act as their consultants, do their own research to solve industrial problems and deliver to them a turnkey product. This obviously the IITs cannot do. IITs can offer only a research solution to some problems. Beyond that there is a long innovative chain. Generally it starts from basic research typically in an organization like the IIT, goes through applied research in the R&D sector of the industry, enabling the industry to formulate prototypes and then lead on to production. IITs can thus be only the first link in the innovation chain. IITs cannot be expected to set up pilot plants. Therefore, when one examines the capabilities, involvement and success of IITs in solution of problems in the Indian Industrial scene, it is necessary to remember that their success is conditioned by the strength of the other members of the chain of innovation. At present the industrial climate in India does not create a demand for utilizing national capabilities like the IIT system. Industry now prefers to go for an international collaboration rather than encourage an IIT to solve their problems. For the IIT faculty, likewise, visits to international seminars, teaching assignments in foreign institutions and career abroad appear to be more attractive than challenges and opportunities available locally. In essence, this is a problem of attitudes both on the part of the industry and the IIT faculty. At IIT Delhi the faculty, in general, have very little industrial experience or exposure.

Reflecting on the centralization of research and development activities at the institute, one faculty member observed:

> At IIT Delhi the important unit responsible for institute-industry interaction is the office of Industrial Research and Development (IRD), which is headed by a dean. In my view, this unit acts only as an additional centralized bureaucracy of an IIT system and it reduces the Institute's flexibility to respond to requests for research and technology transfer services. I would prefer to have decentralized R&D units at major departments. Decentralization makes it easier to deal directly with research problems and to make research contacts.

Most of the junior faculty members viewed that there are no departmental thrust areas for research in which the expertise of staff could be mobilized. They indicated that particular areas of research are generally determined by a small groups of senior faculty members who are also responsible for approaching the funding organizations. They felt that this approach is fairly ad hoc in nature and heavily dependent on the initiatives and interest of senior faculty members. In general they also indicated that lack of advance planning, identification of thrust areas of research and lack of funds affects the research productivity of the staff.

Patents and Technology Transfer

The IITs are special institutions deliberately funded for being well equipped, with the best of faculty, laboratories, workshop and teaching facilities. At IIT Delhi the Industrial Research and Development Unit (IRD) was specifically set up in 1976 to administer industrial R&D activities. But it was only during the last decade that the institute placed greater importance on strengthening interaction with the industry. The issue of the relationship between technical institutions and industry, and the complex of questions it gives rise to, came to the forefront in the late 1980s with the introduction of the liberalized industrial policy by the Government of India. Hence the issue of patents and technology transfer in academic institutions is a new one in India.

Some of the technologies that have been transferred to industry or which are ready for transfer are given below to illustrate the range of expertise available at IIT New Delhi (Indian Institute of Technology, New Delhi, 1992) :

- Ferrite Phase Shifter for the Missile Project.
- Anaerobic Biomethanation Technology for treatment of distillery effluents.
- Charred Biomass Briquette Fuel.
- NMR Spectrometer for evaluation of content of oilseeds.
- Instantaneous braking system for induction motors (up to 50 hp).
- Twin Cassette Recorder.
- Biomass fueled gasifier engine set.
- Bioconvertion of Lignocellulose Biomass into Ethanol.

- Braille duplication sheets and duplication machine.
- Transfer printing process for transfer of design of 100% Polyester Cotton blended fabrics and garments.
- Automatic gauging and stamping machine.
- Pressure Welding machine for steel reinforcing bars.
- Fusion splicing machine for optical fiber joining.
- Fiber optic based liquid level sensor.
- Weighing machine.
- Haemoglobinometer.
- Hand held medical data entry system.
- A Novel generator for portable generating set.
- Computer-based text to Braille conversion.

The status of the above technologies in terms of their applications and uses was not provided in the IIT Annual Report 1991-92.

With respect to specific technology or know-how transferred to industry, the Center for Biomedical Engineering is an outstanding example at IIT Delhi. In the area of rural health care the center was able to develop successfully a rural health worker kit that included a folding weighing machine, haemoglobinometer which is independent of volumetric measurement, and a microprocessor-based medical data recording unit. This know-how was also transferred to local small-scaled industries and on a trial basis the kit is used in about 21 Primary Health Centers spread around India (Guha, 1991). A small beginning in technology transfer has been made at the laboratories of the Biomedical Engineering Center at IIT Delhi and the All India Institute of Medical Sciences. The Center has also developed a new concept enabling the blind to read text as well as diagrams from a computer-monitor screen. Viewing diagrams and text from computer screen has been made possible by a special software that converts characters/diagrams into illuminated Braille dots/forms on the screen. The blind can read the output by a combination of photo sensor and a vibrator. The system received the National Invention Award from the Government of

India for the year 1991. A company in New Delhi has also been given the know-how for the text and Braille conversions. A computer software package developed by the Center called DIGI-CEPH used for dental orthodontic corrections is also marketed by Electronics Trade and Technology Corporation in India.

The department of electrical engineering and the center for applied research in electronics has also been successful in developing instruments/equipments and software packages that were generally used by Government departments like the department of electronics and the department of defense. Some of the technical know-how on design and fabrication (12.2 mm modified C-band Ferrite phase shifter and Axle counting system for automatic signaling) has also been transferred to industry for production.

Foundation for Innovation and Technology Transfer (FITT)

With a view to achieving a quantum jump in the level of collaboration and interaction with industry and other user organizations on programs of mutual interest, a Foundation for Innovation and Technology Transfer (FITT) was set up at IIT Delhi on July, 1992. The Foundation as an autonomous registered society has administrative and financial independence from IIT Delhi but draws upon the IIT Delhi as its primary resource, supplemented by expertise in other IITs, R & D organizations, consulting engineers, marketing and management experts to serve industry and other user organizations. The Foundation has a governing council in which the Director of IIT Delhi acts as the Chairman (Ex-officio) and there are representations in the council from large-scale industry, medium-scale industry, small-scale industry, industrial associations, financial institution, ministry of human resource development, IIT Delhi senate and the board of governors.

Operating across the technical and academic components of IIT Delhi, the Foundation aims to improve communication between industry and IIT Delhi, to provide an effective delivery system for technology development of research ideas emanating from its research and teaching laboratories and to focus the resources of the institute on the strategic needs of the industrial community (Foundation for Innovation and Technology Transfer, IIT, New Delhi, 1992). FITT undertakes the following major programs to further industry-institute cooperation (FITT, 1992):

(1) Product Development Program: This program supports technology development leading to commercialization of products and process at specific request of industry as well as those emanating from in-house developments with a potential for industrial applications. The program also aims to generate comprehensive data bank on all technical work being done at IIT Delhi including students projects, faculty research, faculty expertise as well as infrastructure facilities available at the institute.

(2) Technology Initiatives Program: This initiatives support technology thrusts at the IIT Delhi by augmenting or creating capabilities which are important to industrial development. Under this program a significant portion of the resources of the Foundation will be set aside to foster exploratory work in identified generic areas of technology that may lead to commercial products on a long term basis.

(3) Technology Advancement Program: The main aim of this program is to promote science and technology park in the vicinity of the Institute for entrepreneurship development through a business incubator program. In the incubator program, technical and business assistance is provided to young entrepreneurs engaged in the development of technically oriented product or services.

(4) Information Support Services: Under this initiative, information support services such as bibliographic services, abstracting services, patent search, technical expertise (IIT Delhi) profiles will be provided to industry and user organizations. FITT will also establish links/networking with international and national data-bases.

The Foundation has also established an extension office in an industrial district called NOIDA which is situated near Delhi. The extension office of FITT which was opened in 1993 aims to facilitate the transfer of technology from the corridors of IIT Delhi to entrepreneurs and help them expand or diversify their products. The office had access to

IIT computer resources, library, and national and international data base through a computer terminal.

The 1986 Nayudamma Review Committee also carried out an appraisal of research interaction of the IITs and industry. In their report they have indicated an urgent need for a permanent unit linking the IITs and their research nucleus with industry and their problem. They have indicated their concerns in the following terms:

> The lack of strong industry-IIT linkage has led to the present situation where;
> -the faculty, in general, have no industrial experience or exposure;
> -there is no provision for continuing education in the IITs for practicing engineers to update their technology competence;
> -state-of-art in the industry prevents flow between organized research in the IITs and evolution of industrial R&D;
> -there is no link person available in most of the departments of the IITs;
> -some of the IITs feel constrained to accept contracts with time bound results.
> The remedy to this situation lies in each IIT having a professional unit like the proposed industrial Foundation working on commercial lines. It is equally necessary simultaneously to ease the chronic dependence of our industry on foreign collaboration and reward the industry for sending their problems to IITs and other Indian academic bodies (Indian Institute of Technology, 1986, pp. 27).

The role and impact of the Foundation for Innovation and Technology Transfer (FITT) in the technology transfer process

As the establishment of the Foundation for Innovation and Technology Transfer was a significant step in institutionalizing the technology transfer dimension, more focused interviews were conducted with various faculty members and officials responsible for organizing the Institutes' research and technology transfer activities. In general the interviews were focused in the following key areas of concern and issues related to technology transfer and the role of the engineering institution:

* Is IIT Delhi an underutilized resource which could assume an expanded role in stimulating the Indian economy through various technology transfer initiatives?

* Planning for research and technology transfer.

* How involved should engineering institutions be in the business end of the transfer process?

- * Was it necessary for IIT Delhi to establish separate office for technology transfer and innovation? What were the reasons for the establishment of FITT?
- * How necessary are these offices ?
- * How effective are the different mechanisms for technology transfer ?
- * Problems encountered by faculty members in transferring their know-how to the society.

Texts from the interviews are also presented. They are not intended to provide answers to these questions, but to elaborate on them and to indicate some of their more interesting features.

The majority of the respondents indicated that the establishment of a separate office for technology transfer activities (such as FITT) was merely the product of a period of financial restraint, that is, either they are forced on IITs or IITs are setting them up in a attempt to find new sources of income. At IIT New Delhi, the level of funding from the Government is frozen at the 1991-92 level. They all agreed that technology transfer from an engineering institutions like the IITs to the society has to be recognized as an important function of the teaching and R&D system.

Most of the respondents emphasized that the technology transfer initiatives are most effective when IITs do research and other forms of collaborative partnership *with* industry and not just *for* industry. Highlighting four major factors that limits the technology transfer partnership, a senior faculty member argued:

> There are four basic factors which limit the capacity of IITs to do any meaningful research and interaction with industry. There is the problem of space we have to work in, the people to do the work, the equipment we have to work with and the bureaucracy we have to deal with. If we look at the facilities and equipment at IIT Delhi, we notice that there is a severe shortage of modern equipment for research. A large percentage of research equipment is bought on sponsored research project funding. So as program funding expands, equipment is procured. In the case of IIT Delhi, the funding for research in constant Rupees (1985-86 level) is decreasing. There is very little hope that the R&D support from the Government agencies will grow in the coming years. So I believe that the increase in basic and applied research must come from the industry. To be successful in transferring knowledge or technique to the society at large, we must do a better job of selling the wider audience on the investment value of research in institutions like the IITs.

Furthermore, a few respondents observed that there is complete lack of cooperation between various organizations involved in the transfer process. In addition, they also stressed that entrepreneurial initiatives of the staff and students should be promoted and rewarded. There was also a suggestion that some mechanism could be developed whereby companies/industries could depute their personnel on the campus for some periods of time for collaborative research, technology transfer and teaching functions. They also indicated that the term technology transfer from engineering institutions should be given a broader definition that includes production of competent engineering graduates, exchanges of faculty members and industrial researchers, support for collaborative projects with industry and continuing education for engineers. It should also include not only the transmission of new knowledge or techniques but also the diffusion of current knowledge. In this context, one of the respondents stated:

> One of the main features of the Indian scientific and technological system is the lack of integration among bodies which create knowledge and those which utilize it. This assertion is based on the lack of knowledge and the scarcity of communication which has separated the industrial sector from the educational, research and training sector, giving rise to mutual feelings of suspicion and distrust. This is the case with respect to the IIT system and the industry in India. There has been no effort to foster general awareness at all levels of the importance of technology in the process of development and of the fundamental role to be played in that development process by engineering education and training establishments and research institutes.

One faculty member noted that IITs should do more basic instead of applied research with industry in a collaborative mode. He opined that this sort of programs would free up industry to concentrate more on applied research, which they are better qualified to do than are technical institutes or universities. However, the majority of the respondents observed that in a developing country like India, technology transfer efforts and initiatives from engineering institutions should focus more on the application dimension of research and should focus on solving engineering problems of a practical nature rather than pure or abstract subjects.

Most of the respondents also agreed that formal and informal communication networks are a vital ingredients in the development of technology transfer programs and initiatives from the corridor of the IITs to the society. Reflecting on this concern, one respondent observed that engineering institutes have often neglected to establish close ties with industry and to promote a flow of knowledge concerning innovations from its centers to places where innovation can be exploited commercially. He also noted that sometimes institutions like the IITs do not want to be presented with a problem. They do not want to enter into a problem-solving mode. They do not want a contract with industry; they want a grant from Government agencies which lets them do things they want to do.

Presenting an over-all status of technology transfer initiatives in India and the role and impact of engineering institutions, one of the senior faculty member articulated:

> I do not think that the emphasis at the IITs has yet been, to any measurable extent, on the process of technology transfer. It would appear that issues of technology transfer would receive progressively higher attention in the emergent phase. The role, therefore, of these institution has been to enable the usability of technology without really responding to issues of the origin and transfer of technology. National laboratories have been set up concurrently with the IITs as basic instruments of technology development. And it will be useful to remind that in the earlier stage of conception of the IITs, they were basically meant to produce engineers, which means undergraduate education, and quality comparable to the west. What has happened in the last 15 years is that in several of the IITs the number of postgraduate students has grown to nearly as large as that of undergraduates. People have been talking of the role and impact of the IIT system as a whole in the economic development of India. What they still have to work out is the internal distribution of time, on research and teaching, in our system as a whole. At IIT Delhi, the issues of technology transfer, manpower development and skill formation is something which has been responded to but is really not in focus yet.

Research productivity measured in terms of publication

How efficient and effective is IIT Delhi in producing research results, at least as measured by publication in various national and international journals is given in table 9. Similarly active sponsored research projects in engineering and science per principal investigator for the different departments and centers at IIT Delhi during the year 1991-92 is given in table 10.

Table 9
Number of research papers produced in the year 1991-92

Department	Number of research paper published	Number of faculty members publishing the papers	Total number of faculty members in the department	Faculty members with Ph.D.
Department of Applied Mechanics	16	7	25	22
Department of Chemical Engineering	25	10	20	19
Department of Chemistry	39	14	26	25
Department of Civil Engineering	42	16	40	33
Department of Computer Science and Engineering	16	12	34	22
Department of Electrical Engineering	50	18	49	47
Department of Humanities	14	4	17	15
Department of Mathematics	36	13	25	24
Department of Mechanical Engineering	35	15	41	37
Department of Physics	56	21	42	40
Department of Textile	46	11	20	17

Source: IIT Delhi Annual Report 1991-92, complied by the author.

If we look at table 9, it is apparent that very few faculty members are publishing research papers in refereed journal. As an illustration, in the department of civil engineering, out of a faculty strength of 40 only 16 faculty members published 42 research papers in refereed journal. The situation in other engineering departments is also similar. In the more fundamental fields such as mathematics, physics and chemistry, about fifty percent of the total faculty members did publish research papers in the year 1991-92.

TABLE 10

Active sponsored research projects per principal investigator at IIT Delhi during the year 1991-92

Department	Number of principal investigator	Projects per person	Total faculty members
Applied Mechanics	3 1	1 3	24
Chemical Engineering	4 1	1 4	20
Chemistry	4 5 1	1 2 3	26
Civil Engineering	4 2	1 3	40
Computer Science and Engineering	4	1	34
Electrical Engineering	7 2	1 2	49
Mechanical Engineering	5 1	1 3	41
Physics	11 4 2 1	1 2 3 4	42
Textile	2 1	1 4	20
Center for applied research in electronics	4 1 2	1 3 5	14
Center for atmospheric science	4 1 1 1	1 2 3 5	20
Bio-Chemical engineering research center	5	1	16
Bio-Medical engineering research center	3 2 1	1 2 5	10
Center for energy studies	8 1 1 1	1 2 3 4	29
Industrial tribology, machine design and maintenance	4 2	1 2	16
Instrument design development center	6	1	18
Center for management studies	1	1	8

Center for material science and technology	1 2	1 2	14
Center for rural development and technology	4 1	1 2	8

(Source: IIT Delhi Annual Report 1991-92, complied by the author.)

Table 10 gives a complete picture of the status of sponsored research projects in the year 1991-92 and the number of faculty members involved in the project. As an example, in the department of mechanical engineering, only 6 faculty members (out of 41 faculty members) were involved in sponsored research projects. The table also shows that the number of principal investigators with one project was 5 and the number with three projects was 1.

Curriculum and Technology Transfer

Undergraduate courses of four years (eight semesters) duration leading to the first degree (B.Tech) are being offered in IIT Delhi in subjects like Civil Engineering, Chemical Engineering, Computer Science and Engineering, Electrical Engineering, Mechanical Engineering, Manufacturing Science and Engineering and Textile Engineering.

Postgraduate degree programs of 18 months (three semesters) duration leading to the M.Tech degree are also available in a variety of technical subjects. Similarly Postgraduate programs of 2 years (four semesters) duration leading to the M.Sc degree are also available at IIT Delhi in subjects like Chemistry, Mathematics and Physics.

The Institute also offers 5-years Integrated M.Sc program in Mathematics and Computer Application and 5-years Integrated M.Tech program in Biochemical Engineering and Biotechnology.

Most of the departments offer Ph.D. programs and also offer facilities for post-doctoral research.

Admission to the first year of the undergraduate programs leading to the degree of B.Tech and 5-years Integrated M.Sc and M.Tech programs is made through the Joint

Entrance Examination (JEE) which is held in the first week of May, and is common for all the five IITs. The JEE is coordinated every year by an IIT on rotation (Prospectus, IIT Delhi, 1993-94). Admission to the M.Tech programs is done through the Graduate Aptitude Test in Engineering (GATE) score (70% weight age) and the performance in the interview (30% weight age).

Minimum credit requirements for the B.Tech programs along with detailed breakup of the credits in various categories are given below in table 11. In order to get a B.Tech degree, students should complete 190 (without minor area specialization) or 198 (with minor area specialization) credits.

Table 11
Breakup of the B.Tech. curriculum

Category	B.Tech	B.Tech (With minor area specialization)
Humanities, Social Sciences and Management (Minimum of 12 credits in Humanities and Social Science courses)	16	16
Basic Sciences (subject to minimum of 6 credits each in Physics and Chemistry and 8 credits in Mathematics)	28	28
Engineering Arts & Engineering Sciences (minimum of 10 credits each in Engineering Arts and Engineering Sciences)	36	36
Emerging Science and Technology	3	3
Departmental	95	95
Open Category *	12	-
Minor Area	-	20
Total	190	198

(Source : IIT New Delhi, 1993, Courses of Study, pp.4)
* Out of the total credits shown against open category, at least half should be taken from outside the department.

The credit system is followed at all IITs in which each course has a certain number of credits assigned to it depending on its lecture, tutorials and laboratory contact hours in a week. At IIT Delhi, one lecture or tutorial hour per week per semester is assigned one credit, whereas one laboratory hour per week per semester is assigned half a credit (Courses of Study, IIT Delhi, 1993-94). However, some courses which are preparatory in nature have half the credit weighting of a normal course.

The B.Tech program with the minor area specialization is offered as an option for students whose performance is above a minimum level during the first four semesters. Students who have completed a minimum of 80 credits with a Cumulative Grade Point Average (CGPA) of 6.00 (on a 10 point scale) at the end of the fourth semester, will be eligible to opt for a minor area specialization. Minor area courses start in the fifth semester and will continue in subsequent semesters till the minor area requirements of 20 credits is completed. A certificate stating the title of the minor area specialization that the student has completed will be issued with the degree certificate.

A letter grade with a specified number of grade points on a 10 point scale is awarded in each credit course for which a student is registered. For example, Grade A is equivalent to 10 grade points, A(-) corresponds to 9 grade points, B is equivalent to 8 grade points and so on.

At IIT Delhi, a student must also complete the prescribed number of days of practical training to the satisfaction of the concerned department. Students who complete 100 credits, are eligible for practical training which will be normally arranged in the summer vacation after the sixth semester. At present industrial attachment is of minimum 50 working days (Indian Institute of Technology, New Delhi, 1993).

In 1985 the Association of Indian Universities conducted a study to assess the relevance of IIT curriculum to job requirement in India. In their analysis they found that 33 per cent of B.Tech graduates employed in India had indicated that their courses had very little relevance or total irrelevance with respect to their jobs. Similarly about 43 per cent of the B.Tech graduates in the categories of entrepreneurs, executives and employees of multinational companies did not find the IIT academic program relevant to their jobs (Association of Indian Universities, 1985, pp.22).

In 1985 the Alumni Association of IIT Delhi brought out a Report that highlighted the views and opinions of IIT Delhi graduates and the viewpoint of the industry as expressed by the Association of Indian Engineering Industries (AIEI) with respect to the relevance and impact of IIT education. An important drawback of IIT education as pointed out by the industry was the lack of communication and linkages between IITs and industry in developing new courses or in reorienting existing curricula (Indian Institute of Technology, Alumni Association, New Delhi, 1985). In order to have a better interaction and linkages between industry and the Institute, AIEI made the following recommendations:

(a) Creation of 'adjunct professorship' in IIT for personnel from industry, research institutions and professional bodies.

(b) Creation of 'residency' for faculty members in industry.

(c) Compulsory industrial training for faculty members and joint studies by industry experts and IIT faculty members in projects on emerging technologies.

(d) Industry should be involved in any reorientation of the IIT curricula.

Analyzing the curriculum, it is evident that in the B.Tech program, humanities and management courses represent about 8 per cent of the total credit requirement to obtain a bachelor degree. In the elective category which represent about 7 per cent, most of the courses offered by the department deals with core engineering subjects. For example, in the department of mechanical engineering, 40 courses were offered in the elective category. Out of this 40 courses about 60 per cent were core engineering subjects, 20 per cent of the courses were in the engineering design area and about 20 per cent were management courses.

Curriculum Design and Adjustment

Curriculum design and adjustment is an important dimension in an engineering institution. From a technology transfer perspective "how *relevant* and *complete* is the undergraduate curriculum at IIT New Delhi?" This question was asked during the interview sessions with the faculty members and the people from the industry. It was not surprising that different views were expressed by faculty members and people from industry. One of the faculty member stated:

> The main aim of the IITs is to produce competent engineer-scientists. The graduates from our B.Tech. programs are expected to be employed in research, design and development and teaching. In this context, the IITs have been emphasizing a science-based engineering curriculum. We do a very good job in producing that category of technical manpower. More recently, we hear complaints that IIT graduates does not have "hands-on" experience and are not suitable for Indian industries, where R&D activities are minimal. They suggest a complete overhaul of the engineering curriculum and make it directly applicable to various industries. My argument is that we can not do everything in the given time frame. One cannot expect academic institutions to prepare "turnkey" products that can fit in all situation.

Similarly one of the respondents from the industry emphasized that the IIT graduates are not adequately prepared for the industries and most graduates have difficulty making the transition from classroom to employment in industry. He indicated that the current conceptual gap between campus and work place is wide and suggested that engineering education should model itself on medical preparation and include clinical training and internship scheme. He further argued:

> The IIT curriculum tends to be too theoretical and too abstract. From a technology transfer perspective, we furnish the engineering graduates with a great deal of knowledge (purely cognitive content) but pay very little attention to their ability to transfer and use this knowledge in a competent and effective way. Engineering is a mission-oriented discipline. Students should not only be good in analysis and problem solving but also be excellent in synthesis and in current awareness.

A common theme links all of these statements: a greater flexibility is needed in curriculum design and adjustment. All the respondents noted that the issue of systematic integration of practical experiences into the engineering curriculum should be addressed. Concurrently, they also emphasized that the traditional engineering curriculum in engineering schools in developing countries should somehow come to grips with the need of entrepreneurship and technology transfer. Entrepreneurial and technology transfer attitudes should be promoted throughout an engineering schools and organizations.

Summary

Eighteen faculty members from IIT, New Delhi and two senior managers associated with industry in India were asked questions related to the institutional development of IIT and the responses and role of engineering education institutions toward transfer and management of technology.

The majority of faculty members interviewed reported that IIT graduates were excellent engineer-scientists and the emphasis at the IIT is on science-based engineering curriculum. However, respondents from the industry felt that IIT graduates do not have any practical "hands-on" experiences and are not suitable for Indian industries, where R&D activities are minimal. They were also concerned that most graduates have difficulty making the transition from classroom to employment and recommended that engineering education and training should model itself on medical preparation and include industrial training and internship scheme. Several of those interviewed were concerned about the ability of the IIT graduates to transfer and use engineering knowledge in an effective way. Younger faculty members also noted that from a technology transfer perspective, IIT students need to be specifically groomed to meet the challenges of Indian industry and the community at large. Younger faculty members tend to be more interested and willing to undertake a more aggressive stance in developing interface opportunities and arrangements with industry and the community and initiate various technology transfer activities.

Many faculty members reported that it is increasingly difficulty to initiate any technology transfer activities from IIT New Delhi. The problems in initiating technology transfer activities from engineering education institutions include various factors such as low research funding, centralized form of management, lack of institutional leadership, inadequate faculty incentives and reward policies to recognize involvement in technology transfer activities, lack of communication among the various participants (user groups, faculty, administrators etc.) in the transfer process and low level of faculty involvement in technology transfer decision making processes. One of the strategies for dealing with these barriers, in the respondents' views, would be to promote technology (knowledge) transfer as a major mission/theme of engineering education institutions in developing countries. All the respondents suggested that IITs must interact with industry and should assume an expanded role in stimulating the economy. The interviews reinforced the notion that entrepreneurial and technology transfer attitudes should be promoted throughout engineering education institutions.

Several of the faculty members interviewed were concerned with the proliferation and working of "research centers" at IIT, New Delhi. This was an issue that came up frequently during the interviews. Research centers were mainly established to initiate time bound interdisciplinary research and development activities, drawing talents from departments within the institute and outside research organizations. However, some of the respondents felt that, in course of time, instead of fostering research interaction and coordination, majority of the research centers move on their own with very little communication with academic departments. Many faculty members observed that research centers were basically created by influential faculty members (who had contacts with government officials) to serve as power base to promote their own personal research interests. They expressed the view that no research centers should be established unless its goals and objectives complement with the mission and strength of the institution.

Finally, the majority of those interviewed recognized that in a developing country, technology transfer efforts and initiatives from engineering education institutions should focus more on the application and use of knowledge and research results and should encourage on solving engineering problems of a practical nature rather than pure or abstract subjects.

Chapter 6

ANALYSIS OF DATA II: IDENTIFYING AND CONSTRUCTING THE KEY THEMES ON TECHNOLOGY TRANSFER

Introduction

The concerns and issues raised in the process of interviews with the faculty members and other individuals in this study take on a thematic form in this chapter. In Chapter V the responses, issues and concerns of the respondents were presented in a general format. Through questioning the data and reflecting on the conceptual framework (engineering education - technology transfer - economic development), I have tried to engage the ideas and the data in significant thematic forms. Here the aim is not to search for exhaustive and mutually exclusive themes or categories, but instead to identify and discuss the salient, grounded categories of meaning held by the participants. The methodology used in this analysis is discussed in chapter III (see especially pp. 48-50). In this chapter the perspectives of the respondents are also presented in order to provide a structural framework for the report. The presentation of themes is, therefore, an effort to understand technology transfer as a process of change and explore the various factors which condition any technology transfer partnership between engineering institutions and the community.

In this study an attempt has been made to come to some understanding of the meaning of technology transfer initiatives from engineering institutions and identify the various issues confronting engineering institutions in initiating transfer activities. The following three themes will be discussed in this chapter.

THEME 1. Redefining the role of engineering institutions.

THEME 2. Organizational mechanisms for initiating technology transfer activities.

THEME 3. Modes of technology transfer partnership.

As my research is primarily concerned with engineering education, technology transfer, and economic development, it is helpful to understand the relationships between the themes that emerged and the assumptions underlying the study.

The following assumptions are made in the study :

1. Engineering education and training is perceived as an effective instrument of national development.
2. Development of technical manpower (technological literate citizens) is a prerequisite for a country to advance industrially.
3. Engineering education itself is a powerful technology transfer process.

In the following section, various themes that emerged from the issues and concerns raised by the majority of the respondents of IIT Delhi with respect to the research topic of conceptualizing engineering education and training system as a technology transfer process are discussed.

Theme 1: Redefining the role of engineering institutions

During the interviews at IIT Delhi, the main research question focused on the conceptualization of engineering education and training system as a technology transfer process facilitating economic development. With renewed attention to the utility of engineering institutions, certain basic questions were also being asked. "What should be the role of IIT Delhi in the transfer and management of technology in India?" "How can this role best be carried out?" In this context, redefining the role of engineering institutions in developing countries was identified as a major issue in the field of transfer and management of technology. This issue was also addressed during the interview sessions with the faculty members.

The respondents outlined that engineering institutions like IIT Delhi constitute a significant *underutilized* source of technical knowledge and technological innovation. Despite these realities, they viewed that technical institutes could play a crucial role in promoting technological change and technology transfer. First of all, engineering institutions make their vital contribution as a mechanism of technology transfer through the training of engineers. Production of the right type of engineering graduates are viewed by all the respondents as an effective means of technology transfer from academic institutions. Ten of the respondents (out of the eighteen respondents from IIT Delhi) felt that production of competent engineering graduates is a powerful mode of technology transfer and indicated that engineering institutions like an IIT should be viewed as pools of technical expertise and creativity that could be tapped directly through the active involvement of academic scientists and engineers in the process of transfer and management of technology. They emphasized that producing an efficient technical work force for economic development should be the prime objectives of engineering schools. They also indicated that although several barriers between academia and the community still exist, awareness of possible complementaries is growing slowly in the developing countries and , as a consequence, the emphasis on direct linkage mechanisms between both sectors should be intensified.

Two respondents felt that IIT Delhi was like an ivory tower, detached from society. In this connection, they maintained that the present structure and the role of the institute did not allow much room for improving the situation because effective and strong leadership is missing at the institute. Some respondents suggested that IIT Delhi is an institution dedicated solely to achieving specific national goals of producing highly trained engineers and scientists.

All the respondents commented that increased interaction between engineering institutions and the community, business and industry is in the public and national interest and will become part of the goals of most of the engineering institutions in the next ten to fifteen years. Reflecting on this concern, ten respondents suggested that the issue is not whether engineering institutions should play an economic role; rather at issue is the *nature* and the *extent* of that role. They cautioned that the teaching and research role of the institution should not be compromised while developing the economic or service mission of the institute.

Most of the respondents agreed that engineering education and training is a focal point at which knowledge from different sources comes together to shape the design of development projects, and often even the planning of industrial sectors. But in India and in most of the developing countries there is a lack of coordination and integration of various sectors involved in the process of management and transfer of technology and knowledge. In this respect, one of the respondent stated:

> One of the main features of the Indian scientific and technological system is the lack of integration among bodies which create knowledge and those which utilize it. This assertion is based on the lack of knowledge and the scarcity of communication which has separated the industrial sector from the educational, research and training sector, giving rise to mutual feelings of suspicion and distrust. This is the case with respect to the IIT system and the industry in India. There has been no effort to foster general awareness at all levels of the importance of technology in the process of development and of the fundamental role to be played in that development process by engineering education and training establishments and research institutes.

Similarly, highlighting the isolation and marginalization of engineers and scientists in the national planning process of technology management in India, a representative view expressed by the faculty members is as follows:

> The record of research and technology transfer initiatives by faculty members at IIT Delhi has been very modest. The interaction between scientists/faculty members in universities and the government is often minimal, and consultation infrequent. With the evident lack of contact between technical institutions and industry, exploitation of any discoveries in the technical institutes like the IIT cannot be pursued to the point of industrializing and marketing innovation. This isolation is further aggravated by the absence of a national science and technology plan to which the research efforts of the IIT system could be put to work to solve society's problems. This should be the real mission of technical institutes like the IITs

On the other hand, there is also some resistance on the part of engineering institutions to greater and active involvement with industry and business for fear that it will jeopardize what is commonly held to be the central role of academic institutions, namely, acquiring and imparting knowledge. In this respect, one respondent articulated:

> Why should we be worried about technology or knowledge transfer? Our job in an academic institution is to impart knowledge and once the student graduates, our job is finished. If we produce good graduates that itself is a form of technology transfer. On the other hand, in the name of technology transfer, if we have to be dependent with the industry and business community for research funds there is a danger that we will lose our academic autonomy and freedom.

However, the majority of the respondents supported the notion that engineering institutions in the developing countries should assume an expanded role in stimulating the economy and economic development and transfer of technology and knowledge should be identified as a major theme of the engineering institution's mission.

Importance of Linkages

Economic development increasingly depends on technological change, and scientific and technological activities are the primary source of that change. In this context, an engineering institution that is involved in training engineers and scientists is but one essential component of a national capacity in science and technology. A nation's scientific and technological infrastructure contains several other types of research, industrial, business and policy-making institutions.

Basically, engineering institutions are expected to produce skilled manpower and expand the frontiers of knowledge in science and technology through teaching and research. At the same time, academic institutions are being called upon to participate even more directly in economic development activities. With this new third function (the other two being, teaching and research) added to its roles, the questions that are generally posed are:

1. How have the engineering institutions in developing countries performed in these multiple roles in the face of mounting pressure for access to engineering education, cascading of scientific and technological knowledge, and the inevitable conflict between the quest for relevance to national goals and the pressure for meeting international standards of scholarship?
2. Are the institutions over-extended?

3. What are some of the major issues in institutional development and institutional efficiency?
4. What are the various linkage/transfer mechanisms
4. What are some of the internal and external barriers to successful knowledge/technology transfer?
5. How to generate faculty interest and involvement in technology transfer activities?

In the U.S. and in most of the developed countries, programs have been developed or are being organized to promote a wide array of industry - engineering institution interactions. An important focus of these partnership has been in fostering and developing appropriate knowledge/technology transfer mechanisms that would contribute in economic development. The flow of ideas from the source and the implementation of technology transfer partnership with industry require not only the generation of an idea but also its evaluation, production, and application (Swanson, 1986). Swanson argued that most studies indicate that the process of moving an idea from the laboratory to common public usage takes an average of 15-20 years (p. 25). He further indicated:

> The complex process of transferring research results into a widely accepted commercial product has not been well understood. Diffusion theories, concepts of adoption processes, and education theories have produced useful insights, but much has to be learned about how the technology transfer process works and how to accelerate it. (Swanson, 1986, p. 25)

The question we have to ask is "has there been a significant change in the institute-industry interactions since the 1980s or the concept of this partnership is just idealistic?". According to the 1993 Issue of *The Chronicle of Higher Education Almanac*, in the United States, the financial contribution of the federal government to research and development activities in doctorate-granting universities was 58 per cent whereas the contribution by industries was mere 6.9 per cent. Similarly the pattern of sponsored research funding for the year 1991-92 at leading Canadian universities is given in table 12.

Table 12
Sponsored research funding ($000) at leading Canadian universities (1991-92)

University	$ooo (Rank)	% Federal Government	% Provincial Government	% Other Government	% Non Government	% Investment	% Increase in total $ from 1987-88
Montreal *	211,949 (1)	36	14		51		118
Toronto	142,958 (2)	58	13	2	23	4	38
McGill	129,540 (3)	49	9	2	37	4	70
British Columbia	126,696 (4)	64	13	1	22		36
Alberta	80,177 (5)	52	25	1	22		36
McMaster	77,923 (6)	39	26		35		42
Laval	76,478 (7)	40	29		31		52
Queens	62,817 (8)	58	12	1	27	2	83
Calgary	59,445 (9)	45	26	1	28		25
Guelph	59,253 (10)	37	47		15		24
Waterloo	54,304 (11)	51	25		24	1	50
Manitoba	51,456 (12)	54	10	5	32		38
Ottawa	50,661 (13)	51	12	2	32	3	54
Dalhousie	47,186 (14)	77	7		16		163
Western Ontario	46,321 (15)	57	12	1	29		24

Source: Canadian Association of University Business Officers (CAUBO) Annual Reports, 1987-88 and 1991-92

* Montreal include Ecole polytechnique and Ecoles des hautes etudes commerciales

Table 12 indicates that majority of the sponsored research funding at Canadian universities still comes from government grants and the contribution from the non-government sector is still very low. At the University of Alberta, the total research funding for the year 1993-94 was around $87.2 million, out of which the Canadian and foreign industries contributed $9.9 million (about 11.4%). The share of the federal and the provincial government was around $62 million (about 71%) (University of Alberta, 1994).

At IIT New Delhi, looking at the statistics on ongoing sponsored research projects in the year 1991-92, about 99 per cent of the funds came from government departments and government research council. Out of the 192 ongoing research projects during 1991-92 only 4 projects came from the private industrial sector. The financial support from the private industries in the research and development efforts is virtually nil. Interactions of the IIT faculty members with industries is through consultancy jobs. During 1991-92, a total of 270 consultancy jobs were undertaken and most of the jobs were with private industries (Indian Institute of Technology, New Delhi, 1992).

Given this context of weak industry-institute interaction in India and to some extent in the United States and Canada, there is a need to develop and initiate innovative technology transfer linkages between academia and industry.

Perceptions of the Faculty Members

Most of the respondents stated that linkage mechanisms with the industry, business and the society should be developed and thoughtful approaches are needed to create an operational nexus between the institute and the community it intends to learn from and to serve. However the orientation and emphasis of the linkage programs should not be at the cost of the main function of an engineering institution i.e. teaching. They also argued that the most enduring contribution of engineering institutions like IIT is through the graduates they develop and not necessarily through various technology transfer initiatives.

Another focus for effective linkage programs, which all respondents identified, was offering programs in continuing education for national development in which teaching, research and service are linked to societal needs. The respondents identified that an important aspect of this programs is the need to develop new strategies and mechanisms in engineering education and training that would ensure that engineers and technicians who are trained are in a position to use their knowledge and skills to contribute to the socio-economic development of their countries.

Attitudes toward Teaching and Research

"What was to be the nature of research in engineering institutions like the IITs?" "Why do you as a professor conduct research?" "Was the emphasis to be put on research which only aimed at pushing the frontiers of knowledge, as generally is the case in engineering institutions in industrialized countries, or was this to be an exercise of technological adaptation and development that relied basically on the use of locally available raw materials and which fitted in with the needs of the country's society?" When these questions were asked of the faculty members interviewed for the study, all hesitated for a moment before answering, for the motives for conducting research are too complex to be described in a few simple words.

The research environment at IIT Delhi is rather fragile. Most of the faculty members who are doing some research and development work have expressed dissatisfaction with the research environment in the institute. Four major areas of weaknesses have been identified. In the first place, there is a lack of comprehensive plans and policies with respect to research and development activities at the institute. No study has been conducted on the rationalization of R&D activities at the IIT. Thrust areas for research or research directions to focus staff strength and expertise within the department and centers has not been identified. As a result, faculty members work very much on their own and there is very little interaction with colleagues even within the department. Due to a lack of leadership role in research and a lack of efforts to organize and mobilize people, the institute has yet to utilize the expertise of all faculty members. Presenting a comprehensive view of research activities at the departmental level, one of the respondent state:

> We are basically a teaching institute and we do a very good job in instruction. Now-a-days there is some pressure from the government to optimize the use of our R & D resources. If we were to improve our research productivity, then it is obvious that a wide a range of features of the departments and the centers would need to be upgraded and improved. Among the more important are the creation of an institutional framework and research policy document that would outline the conditions and facilities for research and the reward system to encourage the efforts and commitments of the staff to do meaningful research. In addition, the department must provide a stronger leadership in research and focus their efforts in specific thrust areas of staff expertise.

The second factor that has affected the research environment is the duplication of research efforts and resources at the departments and research centers. At IIT Delhi, in addition to academic departments, there are 10 specialized research centers. These research centers were mainly established to foster interdisciplinary research in selected areas of importance, drawing talent from departments and outside research organizations (Indian Institute of Technology, New Delhi, 1986). Moreover, the notion of a "critical mass" is also evident behind the creation of some interdisciplinary research centers like Biomedical Engineering, Rural Development and Technology, Biochemical Engineering and Applied Electronics. According to the critical mass hypothesis, some minimum size of researchers is needed to carry out R&D activities efficiently. In order to conduct inter-disciplinary research, research units should have a certain minimum size, the reasoning goes. The objective consists in pooling a sufficient number of researchers from different discipline into one specific research center which might not be available in a single academic department.

Some of the respondents outlined that the centers and the departments are competing with each others for funding for sponsored research. They indicated that this sort of rivalry among departments and centers for research funding can be damaging for the institution. There is also duplication of research facilities and manpower in the research centers and the departments. In a situation where there exists a lack of research manpower and financial resources, one respondent outlined:

> At IIT New Delhi research centers do not generally foster research interaction and coordination. The majority of the centers move on their own with very little communication with concerned departments. This has created a demoralizing effects on younger faculty members. These new faculty members are caught in the middle between two "competing" units in the same organization.

The majority of the respondents indicated that no research centers should be established unless its goals and objectives complement institution missions and strength. They also observed that when centers are created, organizational and bureaucratic procedures and policies must be examined to be sure that they will promote collaborative research with faculty members from academic departments.

The third factor that has affected the research environment is the severe lack interdisciplinary research team concept. Within the department itself, the staff is fairly fragmented in terms of research interests. Very few research projects or proposals are formulated that would have an inter-departmental focus. One of the faculty members articulated that the research centers that were basically established to promote interdisciplinary research and collaboration lack internal mechanisms to accomplish this important function.

The fourth factor relates to the inadequacy of research manpower support. The research grants that are obtained are generally small and adequate only for the purchase of materials and inexpensive items of equipment. One of the respondents observed that the service of graduate students as research assistant is not generally available at Indian engineering institutions. At IIT Delhi most of the graduate students get government scholarships intended primarily for food and lodging and they are not obliged to work as research assistants. The poor support of laboratory assistants or technicians is also a factor contributing to an unsatisfactory and weak research environment.

For a long time, academics and external observers of institutions of higher studies in many countries have pondered the inter-relationship of teaching and research in academic institutions (Lindsey & Neumann, 1988; OECD, 1981). In engineering institutions, academic activities basically come in two major forms: teaching activities and research activities. Central everywhere is the question of how much of a relationship exits among these activities and how it is effected.

Most of the respondents viewed that the question of research depends on two things: availability of funds and facilities and academic interests of staff members. They outlined that in most of the developing countries, there is a serious problem of availability of research funds and the facilities are also not adequate.

However, two respondents who were actively involved in applied research pointed out that the basic desire to conduct research stems not from any external pressures but from the internal intellectual need to follow up their own initial hunches and to develop them as they proceed. Consequently, they perceive success in research as being identical to success as a professor. This perception seems to prevent the faculty members from being tied to any extrinsic rewards in conducting research. In fact, they took pride in the fact that they as researchers are more concerned with intangibles such as the quality of research itself. Similarly, they felt that faculty members must have a professional commitment to the central task of teaching. One of the respondent observed:

> Faculty members have a variety of hidden incentives for conducting research, which are usually buried under the cloak of academism. There are some faculty members who perceive success as lying in research rather than in teaching, and consider success in external service rather than in internal service to be more important because it is the principal route to extending their nationwide reputation in their field. Due to limited time their contribution in teaching is minimal which I think is detrimental to IIT, because IIT is still basically a teaching institution.

Five of the respondents observed that putting a lot of emphasis on research may result in de emphasis of undergraduate teaching and argued that research oriented professors should carry on research activity only in the time available after they have met their primary obligation of teaching. They also advocated that teaching is the principal task of faculty members and observed that research oriented professors tend to sacrifice their commitment to teaching for more research activities.

Faculty Consulting

During the interviews, all the respondents indicated that they looked upon teaching as their primary responsibility. However, some of the respondents observed that due to the very low salary structure for the academics, they are forced to make alternative investments of their time and energy in the form of outside consulting work. In consequence, academics invest disproportionate amounts of their time and energy in obtaining outside consultancies, pursuing investigations and writing reports for their outside consultancy works. In some cases, there is a lack of preparedness with which faculty members approach their teaching responsibilities and are not generally accessible for student consultation.

The question of whether outside consulting by faculty member enhances or inhibits institutional efforts to be responsive to economic development needs is important but difficult to answer. On one side, it can be argued that engineering institutions most effectively respond by encouraging natural and direct linkages between faculty members and outside groups. It can also be argued that allowing faculty members to supplement their salary encourages them to remain on campus and forgo more lucrative positions in business and industry. On the other side, paid faculty consultants can be viewed as "double dipping." It can also be argued that such consulting activities jeopardize the fulfillment of teaching obligations and engender numerous conflicts of interest for faculty members and their institutions.

"Does paid consulting work cause serious conflict of interests for faculty members and institutions?" Some of the respondents indicated that there is an intrinsic conflict of interest between the two roles, academic and paid consultant. They argued that the paid relationship between the faculty member and an external organization subtly shifts the basis for deciding whether to participate in the activity away from criteria of academic benefits toward criteria of monetary and personal gain for the individual. However, they also indicated that a carefully delineated conflict of interest policies and guidelines, more vigorous enforcement of accountability procedures, work obligations and implementing a code of ethics could help minimize the risks of conflict.

On the other hand, some of the respondents argued that the institute should allow and even encourage paid faculty consulting activity in areas related to local, regional, and national economic development. They viewed outside consulting as an effective technology transfer mechanisms and argued that it has to be promoted. A representative view expressed by the respondents is as follows:

> Academics always face a dilemma in striking an appropriate and responsible balance among their competing responsibilities for teaching, research and service to the relevant community groups. If faculty members fulfill their teaching and research obligations in an efficient manner, there is no harm in doing outside consulting works. Furthermore, this type of linkages can enhance teaching by engaging students in real-world activities and enhance research by broadening definitions of problems and worthy subjects to study. If some faculty members are involved in excessive outside consulting activities and in the process neglect their teaching obligations, they should be punished. These alleged infractions of rules by some faculty members should not translates into complete condemnation of consulting practices. To guard against conflicts of interest guidelines and work obligations, however, the institute should develop consulting policies that establish clear limits and ground rules.

Development and Transfer of Endogenous Technology

Another important concern expressed by most of the respondents relates to endogenous technology development. According to Webster Dictionary, the term "endogenous" is defined as "caused or produced by factors inside the system." The majority of the respondents stressed that the biggest obstacle to overcome in order to encourage engineering institutions to become involved in endogenous technology development and transfer is that of orientating the attitude of the staff to work in an area of activity which might appear at first sight to be intellectually as well as professionally inferior, and therefore non-satisfying. Additionally, it would also be necessary to create the awareness among staff of the importance of endogenous technology development and also establish suitable promotional procedures that will take account of staff initiatives in this field of work. The most important constraint on engineering education institutions becoming fully involved and effective in endogenous technology development would be in the area of project implementation. On this issue, the respondents emphasized that engineering institutions should create extension services that will render technical and managerial assistance to industry and the surrounding communities.

Furthermore, one of the respondent observed that the most effective area where engineering institutions in developing countries can have the greatest impact is the development of improved technologies for the small-scale industrial sector, which in turn can respond to the needs of the larger proportion of the population in the rural areas. He stated:

> In focusing attention on this sector, engineering institutions will have the chance to combine the advantages of emerging technologies such as micro-electronics, biotechnology, new and renewable energy technology, and even advances in communication technology, with traditional technologies which invariably rely on the use of local raw materials. This type of strategy when adopted for the promotion of endogenous technology development will remove the uncertainties that are often associated with commonly used concepts such as intermediate and appropriate technologies. It is important to stress that we are not calling for a reduction in academic standards in engineering institutions in developing countries. On the contrary, engineering education system must be designed to produce engineers with sufficient competence to *integrate* technology into complex societal needs that exist in these countries. We need to train entrepreneur-engineers.

Collaborative Research

Most of the faculty members interviewed were aware of the institute's priorities with regard to teamwork and recognized the benefits it could bring in expanding the research capacity of the department and the institute, but they also pointed out certain limitations with respect to initiating collaborative research among faculty. Faculty members emphasized that as far as collaborative research work is concerned, researchers have a tendency to want to adhere closely to their own field of work. They stressed that collaborative work should not be forced but should arise *spontaneously* from a need to add another dimension to an existing project.

Some faculty members were positive about collaborative work, but it transpired that their preference would be for other researchers to fit in with their research agenda rather than vice versa.

Another viewpoint expressed a reluctance on the part of some faculty members to work on collaborative research. Researchers in general tend to want to guard their more significant research findings. It was also argued that there is a competitive edge that is generic to research and some researchers feel that, when attempting to break new ground, their own work must be protected from other contenders to the discovery.

At IIT Delhi, generally large-scale collaborative research projects have not been part of departmental research agenda. However, names appearing on faculty publications might seem to indicate that more collaborative team projects have occurred than is actually the case. An analysis of faculty publications in the department of mechanical engineering indicates that of the 35 papers published in the year 1991-92, 17 papers were written by two authors, 15 by three authors and 2 papers by six authors. There was only 1 paper written by a single author. At an interdisciplinary level, there were very few publications indicative of collaborative research. Looking at the authorship of papers, it is difficult to ascertain the degree to which the listed authors were involved in the research while it was in progress. It may be possible that a second or third author on a research paper means that these authors read and commented on the paper or funded it or provided space or equipment but were not actually involved in the research.

Theme 2: Organizational Mechanisms for Initiating Technology Transfer Activities

Developing successful technology transfer initiatives from engineering institution requires attention to the organizational mechanisms that will make possible the transfer of knowledge/technology embodied in the system to the community. These organizational mechanisms translate the goals and objectives of the institution into specific plans of action. From the interviews and literature review, four such organizational issues are evident:

1. Need for a "organization champion" to promote, oversee and guide technology transfer activities.
2. The selection of "organizational form" of units responsible for technology transfer activities.
3. The type of "organizational linkage" for structuring technology transfer services.
4. The extent and timing of "organizational controls" that will be used to ensure progress in achieving the objectives of technology transfer initiatives.

Do We Need "Champions"?

An immense body of research has examined leadership in organizational settings. By leadership, most people mean the capacity of someone to direct and energize the willingness of people in social units to take actions to achieve goals (Rainey, 1991, p.157). In the area of technology transfer initiatives from academic institutions, entrepreneurial leaders and policy innovators have played an important role as "champions" in mentoring and initiating successful technology transfer partnerships. Dorfman (1983) and Matkin (1990) argued that the early successes of a few entrepreneurs (champions) powerfully influenced the direction and magnitude of the growth of Silicon Valley and Route 128

All the respondents in the study were asked about the role and impact of "champions" in formulating and organizing technology transfer activities. In this usage, the leadership role of champion involves the crucial functions of championing goals and values, setting direction, and inspiring others to work for the technology transfer mission. All the respondents indicated that there is a need for visionary leaders who can effectively transmit the technology transfer vision to others in ways that give meaning to their work and their quest.

One of the most important findings of the study points to the role of the professor-champion-head in the department or research center in creating a momentum for technology transfer initiatives. Despite the presence of many other factors, the champion remains the key figure in the creation of various transfer partnership in his or her departments/centers.

He/She has to be academic and entrepreneurial at the same time. However, some of the respondents identified that in order to make the technology transfer initiatives from engineering institutions a success, "champions" should not just be at the top, they should be at all levels of management.

At IIT Delhi, most of the respondents observed that director and deputy directors who are supposed to provide the leadership role in the institute are pressed for time and demands from people outside the organization have a much stronger influence (especially in the case of the director) on how they manage their time. They have very little time in motivating, and communicating with, faculty members and other employees. Furthermore, a few respondents indicated that director and deputy directors carry out their work under conditions of constraint and intervention from the political and administrative environment. One of the respondent observed:

> The director who is the chief executive officer of the institute is often bogged down with routine administrative works and in finding solutions of interpersonal and interdepartmental problems. At the IITs, there are few role model for technology transfer and entrepreneurial leadership.

Similar comments and reactions were also received from IIT Delhi alumni. In a study done in 1985 by the Alumni Association of IIT Delhi, some of the alumni noted that there was no champion or role model at IIT Delhi. They were of the opinion that visionary leaders were essential for an IIT system not to be deterred from its quest for excellence at any cost. One of the alumni presented a very interesting comparison between IIT and the Indian Institute of Management (another institute of national importance). He stated:

> I had realized by then that my IIT education, though great for a start, was inadequate to unravel some of the complexities of our society. I badly felt the need to study more thoroughly the disciplines of Economics, Organization Theory and Management. I joined the two year postgraduate program at the Indian Institute of Management (IIM), Ahmedabad. While it began as a business school, under the guidance of visionaries like Ravi Matthai it has done remarkable work in frontier areas of management - including management of public system and rural development. I was particularly lucky to have gone to IIM Ahmedabad with a predefined scholastic agenda and found the faculty and courses to fulfill it. I did my summer project in Ravi Matthai's Jawala Project, which was a rich learning ground for a dozens of young people in rural development....I feel that my IIT education was tremendously useful in helping me in building myself as

> a well-rounded person. This was possible because of a significant content of humanities and social sciences in the curriculum. I think it is a pity that most fellow students looked at these courses with contempt. I also benefited greatly from the plethora of extra-curricular activities at IIT because they opened up my world-view as well as helped build my organizing ability. Yet I think IIT education is deficient in many ways. One feels this most when comparing the IIT to an institution like IIM Ahmedabad. At the IIT, there is inadequate vision at the top amongst the faculty, there is a narrowness of world view, there is a lack of examples of excellence and of devotion to one's work. This I say with the fullest respect for some individual members of the faculty who display these qualities. These beacons will have to shine brighter before the IITs graduate from being institutes of excellence to becoming institutions fostering excellence. (IIT Delhi Graduate, 1975, Alumni Association, 1985, pp.57)

Two of the respondents who had initiated some amount of successful technology transfer activities in the field of bio-engineering indicated that "champions" should motivate followers by recognizing their needs and providing rewards to fulfill those needs in exchange for their performance and support.

Technology Transfer Leadership

Engineering institutions are organizations which are professionally staffed and have to be professionally led. In professionally led organizations, "what are the important attributes a leader should have in order to provide the most effective form of technology transfer leadership?" In investigating this question, the following important concerns/issues were highlighted by the respondents. There was also a broad consensus among respondents over the following issues.

1. In general, leaders in academic institutions use authoritarian style of leadership. They use their authority of the office to demand compliance with their wills. This style of leadership relies on power in a controlling mode which is not suitable in an academic environment and in conducting technology transfer partnership with the community.

2. Cooperation in technology transfer initiatives is more easily extended in publicly funded engineering institutions (like the IITs) if the leadership and decision making process is based on shared professional culture, rather than in the form of line management

directives reflecting just the interests of the government beaurocrats or the industry or business firm.

3. Generally, technology transfer leadership in engineering institutions involves an emotional and intellectual component. The emotional component could be categorized as the intangible attribute such as charisma which can have inspiring influence on many people to work for the transfer mission. The intellectual component which is more important in an academic institution involves careful attention to individual intellectual and developmental needs. This type of leadership accepts the legitimacy of professional values and expertise of staff to share in the decision-making process.

4. The technical competence of the "champion" is of paramount importance and should not be underrated. It should be the most important criterion for the leader's influence and effectiveness in any technology transfer partnership. People often admire and follow primarily because the champion is very good at what he or she does.

5. Interpersonal and communication skills are vital in any technology transfer initiatives. "Champions" with these skills effectively create visions of successful transfer partnership and they have to provide rewards and reasonable clarity of goals and directions.

There was a broad consensus among respondents over these issues.

Organizational Form of Units Responsible for Technology Transfer Activities

The respondents were asked questions related to the types of functions, structures and objectives of offices/units responsible for technology transfer activities. The question of location of such units was also discussed during the interviews.

At present, there are two units at IIT Delhi that deal with technology transfer activities. One unit which is named Industrial Research and Development (IRD) was established in 1976. The main objectives of the unit was to provide consultancy services to the industry and to process, secure and administer sponsored research projects from industry and other research institutions. The unit also has a mandate to assist faculty with patenting, licensing, and contracting research. The unit is headed by a dean and is under deputy director for academic affairs.

With a view to stimulate research, development, and technology transfer activities from IIT Delhi, a second unit which is named Foundation for Innovation and Technology Transfer (FITT) was set up at IIT Delhi on July, 1992. The Foundation acts as an autonomous registered society and has administrative and financial independence from IIT Delhi but draws upon the IIT Delhi as its primary resource, supplemented by expertise in other IITs, R & D organizations, consulting engineers, marketing and management experts to serve industry and other user organizations. The Foundation has a governing council in which the Director of IIT Delhi acts as the Chairman (Ex-officio) and there are representatives on the council from large-scale industry, medium-scale industry, small-scale industry, industrial associations, financial institution, ministry of human resource development, IIT Delhi senate and the board of governors.

The Foundation also has a provision of Corporate Membership. Industries, industrial/business organizations, user service organizations, research and development organizations and financial institutes can become a Corporate Member of FITT by paying an annual membership fee. The corporate members are allowed free access to the library and to various information support service programs such as the on-line access to international databases (DIALOG) and national databases (INSDOC).

Separate offices for initiating technology transfer activities from engineering institutions are recent phenomenon in Indian higher education. These offices for technology transfer have evolved from earlier research management structures. On the question of whether engineering institutions should set up separate offices for technology transfer activities, all the respondents observed that there should be a separate office to handle the various R&D efforts and technology transfer initiatives. However, respondents held conflicting ideas regarding the location of such offices. One of the key issues revolved around the question of whether institutional outreach to participate in technology transfer initiatives should be organized in a centralized or in a decentralized fashion. Some noted that technology transfer offices should be located at the department and development of industrial and business opportunities should be conducted as close as possible to faculty. They argued that there are some clear advantages to decentralization, with various departments and centers each taking responsibility for the development and delivery of its own technology transfer activities. In the views of the respondents, centralized technology transfer offices create additional bureaucracy and hence reduce the institute's flexibility to respond to requests for services. Centralized administrative systems and lack of cooperation and immediate involvement from the faculty members seem to be the crucial problems in initiating technology transfer activities from engineering institutions.

According to one of the respondents, the establishment of FITT is seen as merely the products of a period of financial restraint and was mainly set up in an attempt to find new sources of income. The same respondent also pointed that there is very little interaction between the officials of FITT and faculty members and managers of FITT are not fully informed of faculty members' research interests.

Some of the respondents indicated that because technology transfer is a time-consuming exercise and requires the talents of rather special individuals who are equally acceptable to faculty and the business/industrial community, the objectives of the technology transfer office should be different than that of the department. Hence the offices should not be located at the departmental level, but should be established at the central administration level. Proponents of this approach observed that centralized technology transfer offices fit better into the overall service mission of the institute and provide one central locus to stimulate transfer activities and also to sensitize all participants to their special needs, perspectives and opportunities. They also provide business and industry with a single office for advice, contacts, and research information. Reflecting on this concern, one respondent argued that if technology transfer offices were located at department and faculty, it will be very difficult for an outsider to know where to make contact and problem will also arise if several departmental offices of technology transfer in an institution like IIT individually formulate or interpret the overall regulations and procedures of the institute. He also observed that decentralized operations are likely to be more costly in the aggregate, duplicate efforts, and confusing to many potential clients who require the services of more than one unit. Most of the respondents indicated that there is a growing need , particularly in technology transfer partnership programs, for a *breadth* that cuts across the boundaries of any one collegiate unit.

All of the respondents felt that there were very few discussions and deliberations between faculty members and senior management when FITT was established. As a result, very few faculty members were aware of the objectives and goals of FITT. One of the respondent stated:

> At IIT Delhi we have an Industrial Research and Development (IRD) unit set up to take care of all technology transfer activities. Without evaluating the effectiveness of the IRD unit and without any consultation with faculty members and other stakeholders of the institute, we create a another bureaucracy like FITT to do a similar job as was done by IRD unit. Those responsible for making technology transfer policy decisions seldom work and consult with people directly involved in these transfer activities. As a result, transfer partnership plans and programs are generally decided on the basis of untested assumptions. Such a state of affairs suggests that a lack of commitment is evident at every level of academic administration, thereby diluting the technology transfer effort.

In his view, policy makers at IIT Delhi gave limited attention to understanding the academic culture of the institution with respect to technology transfer issues and policies and did not make any attempt to reach a consensus on structuring technology transfer services at the institute.

One of the respondents noted that the resource commitment to FITT was quite negligible and in such a situation it would be simply wishful thinking to contemplate implementing an extensive development oriented technology transfer program. A real change in the attitude of the faculty members towards effective interaction with industry and business was regarded as crucial to the emergence of a conducive environment for developing technology transfer initiatives at IIT Delhi.

Functions and Structures

Currently at IIT Delhi offices (like IRD and FITT) involved in some form of technology transfer activities offer a range of services including patenting, in-service training, consulting, product development, marketing, administer sponsored research projects and provide research services to industry and business.

Most of the respondents indicated that there are five major elements affecting the functions and structures of technology transfer office. These factors were identified as internal factors and the institution has some amount of control to effectively manage them. The five factors are:

1. Lack of managerial/industrial capacities on the part of the officials who oversee and guide technology transfer office.
2. Lack of reliable information about the need of the user (community, industry, business etc.).
3. Lack of long-term technology transfer plans and policies. In the absence of long-term planning capability, technology transfer officials focus only on short term plans and results.
4. Lack of financial resources.
5. Lack of communication among the various participants in the transfer process.

Most of the respondents indicated that offices for technology transfer activities are not viewed as a permanent part of the academic culture of the institute. One respondent stated:

> In the existing academic culture at IIT Delhi, technology transfer has yet to be recognized as an important mission of the institute. So, there must be a real commitment on the part of technology transfer officials to motivate faculty and students to forge a close relationship with the community, industry and business. This is not an easy task. The technology transfer efforts should be institutionalize into the mainstream activities of the institute.

Comments and reactions of the respondents regarding the fragmented nature of technology transfer initiatives at IIT Delhi confirmed the absence of a comprehensive policy. One respondent observed that technology transfer policies and programs are generally "bureaucratic" in the sense that they were usually imposed from the top. The key role players in technology transfer policy development and program formulation were either senior bureaucrats of different government agencies such as the Ministry of Education, the Ministry of Science and Technology, the Ministry of Defense, the National Planning Commission, and the Ministry of Industry. In essence, the lack of involvement of faculty members and other stakeholders of the institute in developing a comprehensive technology transfer policy was identified as a major obstacle in successfully initiating transfer activities from engineering institutions like the IIT.

Although technology transfer programs emphasized the need for making transfer activities relevant to the real life situation of the users, no significant efforts were made at the operational level at the offices of IRD and FITT.

Organizational Linkages

The establishment of the Foundation for Innovation and Technology Transfer (FITT) at IIT New Delhi in 1992 is seen by the faculty members as the organizational link between faculty and the industry in the area of technology transfer.

One of the organizational linkage program initiated by FITT is the establishment of an extension office in an industrial district called NOIDA which is situated near Delhi. The main function of the extension office which was open in 1993 is to provide technical help and assistance to the various small and medium size industries located at the industrial district. The extension office also had access to IIT computer resources, library, and national and international data base through a computer terminal.

One of the most important issues concerning extension system in technology transfer has been raised over deliverables--what should be the "product" of extension services? Should it be technology (hardware) and its transfer? What kind of technology? Should extension's purpose include delivery through teaching and learning? What should extension deliver? When these issues were presented to some faculty members and official of FITT, responses were mixed.

One group of respondents observed that due to unconsolidated and sketchy policies of the extension office, the deliverables are not well defined and identified. They also indicated that the extension officers who have responsibility to provide an effective delivery system for technology development of research ideas from the IIT, are inadequately equipped for the task. This is true, both in terms of their quantity and expertise. Most of the respondents agreed that the case for expanding such extension activity is strong, but observed that such moves require careful planning, and need to build on current strength of the IIT system. One of the respondent argued that before establishing such extension services, the institutional placement of such offices should be carefully considered and the market for technology transfer should be identified. There could be a case that there was little appropriate technology or technical information to extend. He even questioned how can a group of poorly-motivated, office based extension officers with little relevant technical knowledge and experience be an effective technology transfer agent.

On the other hand the FITT officials were very optimistic about the extension program. They indicated that it will be too early to comment on the effectiveness of the extension linkages as it has just been in operation for about a year. The respondents also indicated that lack of visibility about FITT's existence, its purpose and effectiveness is one of the most important shortcomings.

Most of the respondents agreed that visibility is a common problem in any technology transfer linkage program. Furthermore, highlighting the peculiarities in the engineering communities that pose barriers to the adoption of the industrial linkage model, one of the respondent stated:

> Engineering community is not a close-knit group. There is very little shared values and emotion. This type of situation acts as a forceful barrier for effective communication among its members. In an engineering institution like the IIT, engineering faculty members are a highly diversified group and are not wedded by shared emotions and mission. This is one of the reason why we do not see any inter-departmental research efforts. Due to very

> ineffective communications patterns among engineers, any technology transfer linkage program is a difficult proposition.

However, not all the difficulties arise at the FITT office or its extension unit; sometimes academics are not comfortable with the idea of industrial extension services. They think that linkage/extension services are best suited for technical colleges or polytechnic schools. Moreover, within the engineering institutions themselves, there exist administrative-academic impediments to the smooth functioning of technology transfer linkage efforts. For example, some of the department heads do not place high priority on support of such programs. Furthermore, the academic reward system, as manifested by promotions and tenure, is based upon traditional criteria such as seniority, publications and to some extent acquisition of external funding rather than upon technology transfer and application. One of the respondents strongly argued that unless the academic reward system is changed and credits are given for technology transfer activities, there are serious roadblocks to technology transfer within the engineering institutions as they are now set up.

Diversity poses another problem for the linkage or extension model in technology transfer in the field of engineering. Science and technology cover a wide variety of disciplines. To provide technical assistance for the diverse group, extension or linkage programs need critical mass of resources to make them viable and self-sustaining.

Organizational Controls

The extent and timing of "organizational controls' that will be used to ensure progress in achieving the goals and objectives of the technology transfer strategy is a complex issue. This task requires the selection of types of controls (formal versus informal), their level (casual versus stringent) and timing (concurrent versus post hoc)

Most of the respondents agreed that technology transfer programs are being called on to be more efficient. This underscores the importance of technology transfer cost and financing. They indicated that the primary responsibility of exercising management controls should be given to the concerned academic institution though the technology transfer efforts may be supported financially by the government.

In the area of institute-industry partnership, the conflicts of interest issue is an important one. Some of the respondents indicated that engineering institutions should have a clear and comprehensive guidelines and rules concerning conflict-of-interest; consulting fees; honoraria; equity interests such as stocks, stocks options , and other ownership interests; and intellectual-property rights, such as patents, copyrights, and royalties from such rights. One respondent observed that conflict of interest and other related regulations is primarily an individual and institutional responsibility. It should not be overly stringent and the objective is to accomplish the goals with people working together. A representative view expressed by the faculty members is as follows:

> The objective of the organizational control system should not be to penalize people, making it impossible for people to carry on challenging research and technology transfer activities. The objective should be to make everyone sensitive to their obligations to the public interest. The control mechanisms should be informal in nature and should preserve the freedom for faculty members to select projects, collaborate with other scientists and maintain their independence to pursue their own mission without undue influence from the government or industrial sponsor.

Theme 3: Modes of Technology Transfer Partnership from Engineering Institutions

As engineering institutions in the developing countries prepare to examine or reexamine their roles and relationships to economic development and in establishing a visible link with the community, one of the key areas demanding attention is technology transfer (OECD, 1992., World Bank, 1991). When we talk about the roles and relationships of engineering institutions in economic development, we are concerned with the strategic use of knowledge-based technical resources in the development of local, regional, or state economy. Appropriate roles can be based on teaching, research, or public service--however an institution can best contribute.

There are many forms of technology transfer partnership ranging from the more common forms of research grants and contracts and consulting arrangements with industry to continuing education and training programs, outreach programs like industrial liaison programs, technical assistance programs, research/development parks, business incubator programs and specialized research centers.

Different kinds of technology transfer activities with different tradition, missions, and perceptions have been initiated during the last two decades. Some have been successful, others have failed. In North America, a number of controversies and conflicts about the desirability of various technology transfer partnership between academic institutions and industry have already been discussed in chapter IV. These controversies have generally revolved around three major issues: (1) Is there a conflict of interest on the part of engineering institutions/faculty members when promoting a wide array of industry - institution interaction? (2) With increasing institute-industry/business partnership, is there a threat posed to the traditional academic norm of free flow of knowledge/scientific information? (3) And, whether the autonomy and the critical functions (teaching and basic research) of academic institutions are eroded due to these partnership. Some viewed academia and industry/business as unlikely and incompatible partners (Powers and Powers, 1988). Some concerns were also being expressed that engineering institutions should be cautious in promoting industry - institution partnership and not serve as industrial laboratories, but rather should continue to focus on more fundamental research (Grayson, 1993).

The services that engineering education can provide to promote economic development in the developing countries fall into three general categories: Engineering education can (1) perform basic and applied research, (2) offer technical and management assistance, and (3) provide appropriate engineering education and training programs. To probe these issues, the following key questions were raised during the interviews with faculty members at IIT Delhi and industry officials.

* Is there a need to initiate various kinds of outreach, technical assistance, and public service programs from engineering institutions?

* What is the range of roles engineering institutions can develop in response to meet these new technology transfer challenges?

* What factors determine how effective engineering institutions will be in the technology transfer partnership with industry and business? How are these factors shaped?

* What are the limitations and obstacles confronting engineering institutions in initiating various technology transfer activities?

* How can engineering institutions develop effective strategies to guide their involvement in technology transfer and economic development?

* What are the costs and benefits of involvement in technology transfer and economic development activities? How can such activities support an institution's teaching and research missions?

In general, most of the respondents agreed that the mechanisms of technology transfer partnership from engineering education institutions falls into the following four broads types:

a) Sponsored Research: This category includes all types of contract research which contribute to the process of technology transfer. Consultancy assignments and collaborative research contracts are also included in this category. Many of these technology transfer initiatives are primarily aimed at helping to solve specific industrial and technical problems.

b) Teaching and Continuing Education and Training Programs: The production of high quality engineering graduates has historically been identified as a technology transfer process contributing to the economic development. Continuing engineering education and training programs, extension programs and professional development programs arranged for a specific client are also included in this category.

c) Business/Commercial Initiatives: This recent area of commercial activity in engineering education includes the creation of start-up companies and joint venture companies to market a range of institution's expertise.

d) Technical/Industrial Assistance Initiatives: This category includes a range of extension or outreach programs aimed to transfer engineering skills and knowledge to small business and the community at large.

Sponsored Research

It is generally recognized that research forms an integral part of duties and responsibilities of faculty members in an engineering institution. The dual tasks of investigation and imparting knowledge is considered an integral components of effective engineering teaching. It is also believed that research is also necessary to support and enhance teaching programs. There is thus an implicit expectation for all faculty members to do research and publish.

From a technology transfer perspective, the central issue is the types and forms of research. In general, research can be classified as either "basic" or "applied". If the primary emphasis of a research is on acquiring knowledge for general epistemological, intellectual, or esthetic reasons, the research is classified as being "basic", whereas if the primary motivation is in the possibility of applying the knowledge to other human undertakings, the research is tagged "applied" (Moravcsik, 1983). Moravcsik (1983) further argued that this dichotomy is very ambiguous and vague, because the classification depends on whether we do it according to the researcher's motivation or the sponsor's motivation, because the classification depends on whether we consider short or long time perspectives, because both motivations can coexist in the mind of the same assessor, and for many other reasons.

From an economic development perspective, this classification of research activities has ramifications at many levels of inquiry ranging from understanding the source of motivation for an individual researchers, sponsor's motivation in funding the research, to the establishment of research policies and competitive strategy in engineering institutions. The 'answer' to the issue of "what type of research will promote the technology transfer mission of engineering institutions?", if any universal one exits, is that many factors influence the research-technology transfer process, and that only through working within a tighter set of definitions and levels of analysis and boundary conditions, can meaningful distinctions be made.

Especially in the context of developing countries, where resources are few and developmental problems are massive, the relevance and linkages of research to societal problems should be the focus of all technology transfer initiatives from engineering institutions.

Most of the respondents observed that by far the mostly commonly cited examples of linkage between engineering education institutions and industry was research and development contracts, in which faculty carried out specific research or consultancy for industrial or commercial organizations or government organizations. Most of the respondents identified that this was one of the most common form of technology transfer from engineering institutions. The existence of appropriate expertise within the institution was the critical prerequisite of success. However, some of the respondents observed that, to be successful in technology transfer initiatives, faculty members also need to be more interested to perform "indigenous research" if their work is to have a direct application to the development problems of the community.

At IIT Delhi, faculty members who are involved in research activities traditionally have tended to assign higher status to basic research than to applied research. One of the respondent observed that research in engineering institution of national importance like the IITs should be driven by science and technology not merely by market pull. He indicated that current micro-electronics revolution, superconductivity and biotechnology seem more likely to change existing markets or create new markets than to grow into current ones. University based research in these areas can have significant long-term economic and technical benefit for the institution and the country. Basic research and quality instruction should remain the core activities of engineering institutions.

On the other hand some of the respondents promoted the concept of "indigenous research" whereby research activities should attempt to solve practical problems. They outlined that this research (indigenous) -- transfer paradigm for engineering institutions, particularly in the developing countries, is a necessity not a choice. The respondents indicated various obstacles and hindrances that acted as road blocks in the institutionalization of this sort of alternative model. They viewed faculty reward and promotion system as the main barrier. Presenting a comprehensive view on this issue, one of the respondents stated:

> The faculty promotion system is generally determined by the internal values and priorities of the academic community. Emphasis is placed on basic research leading to publication in scholarly journals directed at colleagues in the profession. More applied work and other forms of transferring and disseminating knowledge such as working on traditional science and technology areas are downgraded. If some faculty members are doing research on rural technology, they have difficulty in publishing their papers in refereed journals and are not valued by the institution. All this creates a considerable divergence between engineering institutions and the rest of society. Hence, the quest for conventionally defined engineering/scientific rigor comes at the expense of relevance.

Some of the respondents also commented that generally in developing countries, whenever a distinction (like in the case of basic versus indigenous or applied research) is made, people also tend to set up a hierarchy of values and status. They were of the opinion that such attitudes do not promote research and technology transfer. Among the respondents, the split on this "basic" versus "applied" research issue was about even.

Another issue that was raised during the interviews had to do with the government sponsored research and its relationship with the institute. Most of the respondents observed that close relationship that has evolved between IIT and government departments has resulted in both benefits and problems. In some cases, the government sponsored research partnership has provided funding for upgrading facilities and buying new equipment. On the other hand, as engineering education institutions became more dependent upon government support of their research, there tend to be increasing pressures on the institutions to provide quick answers, definite conclusions, and to certain extent to accept government control of research results. As the government support grew, it imposed greater regulations. In the process, some of the faculty members observed that commitment to excellence and academic freedom was being compromised.

Dealing with the issues and problems of sponsored research projects for the IIT system as a whole, the 1986 Prof.Nayudamma Review Committee which was formed to assess the overall impact of the IITs on the training of high grade engineers for the technological development of India stated:

> The IITs currently obtain Plan assistance from several government departments who sponsor specific projects with the IITs. While such sponsorship has been of help to them it has also left behind problems with the IITs. Usually a sponsoring authority identifies a Project Investigator in the IIT, who develops a project, works out the cost and finalizes project details. The plan assistance received from government departments is based on the assumption that necessary infrastructure is available in the IIT and it is profitable for the funding agency to utilize existing resources in an IIT instead of investing on their own. In actual practice the sponsored project forces IIT to recruit more personnel such as scientific staff, technical personnel, workshop and non-faculty staff whose appointments are made out of the project funds and to be terminated at the end of the project. When project authorities cease to fund the project at the completion of the task, the IIT concerned is on the look-out for similar projects, where staff already recruited can be further employed, thus transferring the liability of further employment of these personnel on a project-to-project basis.... Hopes are thus built that by such a process they are being permanently absorbed as employees of the IIT.... No IIT can afford to absorb such a large number of staff as institution staff.(Indian Institute of Technology, New Delhi 1986, pp.30)

Teaching and Continuing Education and Training Programs

Historically, as was noted in chapter IV, producing high quality engineering graduates has been identified as an effective technology transfer mechanisms from engineering institutions.

The quality of undergraduate level programs at IIT Delhi is of very high quality. All the respondents (faculty members and people from the industry) indicated that the principal reason for the high quality B.Tech.(Bachelor of Technology) program is due the high quality of student input and a very efficient and fair student selection procedure which is based at an All India level. They also noted that the Institute has highly capable and qualified faculty doing a good job of teaching. The quality of the B.Tech. graduates is clearly reflected by the employment pattern. In the year 1991-92, 243 students graduated from the B.Tech. program in various engineering discipline. Out of that total, 161 graduates (about 66%) were absorbed in the industry in India, 24 (about 10%) went for higher studies in management at the Indian Institute of Management (IIM), 35 graduates (about 14%) went abroad for higher studies and 6 graduates opted for higher studies in India (Annual Report 1991-92, IIT Delhi). It is also interesting to note that about 58 graduates (about 24%) had more than one offer of employment.

During the interviews, all the faculty members indicated that they viewed teaching as their primary responsibility. Some of the respondents also indicated that the industrial training programs for final year B.Tech. students is very useful in giving some industrial exposure to the students. They also noted that this sort of industrial training program helped the students to get employment in organizations where they had undergone the training. One of the respondent observed that about 75% of the students who apply for placement in the firms where they undergo training also subsequently get employment after graduation.

Under the continuing education and training program about 23 short courses were organized during the year 1991-92. The courses are either sponsored by industry or government department for the benefits of their own personnel. Apart from the short courses organized under the Continuing Education Program of the Institute, various departments and research centers conducted about 60 seminars/short courses/panel discussions (Indian Institute of Technology, New Delhi, 1992).

Currently the continuing education and training program is carried out by institutional elements that are peripheral and receive at best limited faculty involvement. One of the respondent observed that:

> Continuing education and training programs has happened by and large in a reactive and ad hoc manner. Though there is a lot of demand from industry and other firms for organizing short courses and workshops on emerging technical issues, this has been largely ignored by faculty members and the

> administration. There is a widespread recognition of the need to provide continuing education for engineers to upgrade their skills and knowledge. One of the solution to meet this need is to institutionalize continuing education, with active support from the industry/business community.

Business/Commercial Initiatives

This mode of technology transfer is relatively novel in engineering institutions in India. Most of the respondents were very hesitant to discuss the economic or commercial value of their research or their knowledge. They argued that the goals and values of business and higher education differ considerably and indicated that issues and concerns such as academic freedom, conflict of interest, research direction (choice of research topic and direction of inquiry), openness and publication and conflict of commitment are very important for faculty members and are generally compromised in any business-institution technology transfer initiatives.

One of the respondents argued that traditionally, in India, professors and teachers have chosen their profession for rewards other than money and this special privilege bestowed by society on the teaching profession was never intended to provide an opportunity for commercial exploitation of their knowledge and skill. He further observed that historically , in India, starting from the origins and development of education in the early Vedic period (around 3000-2500 BC) people involved in the teaching profession believed that their achievement was obtained through service to their students, their institutions, and their disciplines.

Some of the senior faculty members explained that they take great pride in the higher degree of academic freedom available to them in conducting research and communicating their research results. They argued that the things they were doing are "academically interesting" and they should not be compelled to justify the significance of their work just in terms of its economic potential.

In contrast, junior faculty members observed that there was nothing wrong (morally) to explore economic potential of the research work and emphasized that they derived greater personal satisfaction from the direct application of their research work than doing research for research's sake.

It is interesting to note that both the senior and junior faculty members were rather positive about the influence of technology transfer linkages with industry and business on their academic activities. The difference was on the issue of commercial exploitation of knowledge and research results. The concept of technology brokerage companies or spin-off companies is generally viewed by both groups as incompatible to the overall mission and academic tradition of the institute.

Commenting on the different academic traditions in the developed and the developing countries, one respondent stated:

> I completed my Ph.D. from the U.S. in the 80s. In the U.S. it is not unusual for a professor to be a managing partner in a spin-off commercial company. But in India, if I do that, I will not be accepted by the academic community. The main reason is "knowledge should not be exploited commercially." However, I believe that once we have mutual trust, appreciation and understanding between academic institutions and business, these commercial technology transfer initiatives will have some chance of success. Technology transfer between engineering education institutions and industry/business is a matter for individuals. Some faculty members have to make a sincere beginning in this direction and mutual understanding and trust will grow slowly.

Technical/Industrial Assistance Initiatives

The establishment of FITT is taken by most of the faculty members as a technical assistance initiative to provide a more coherent representation of the institute towards the outside world, and to increase the number and scope of contracts between the institution and the industry by exploiting the expertise at the IIT.

Two competing views about the roles and impact of these outreach initiatives were evident. Some of the respondents articulated that in initiating technology transfer activities from engineering institutions, there is the very real danger of functional overload. Technology transfer partnership can absorb a large part of time and energy of the faculty. They observed that not only can the quality of performance of the traditional function (teaching) be seriously compromised, but the quality of performance of the new transfer initiatives could be equally compromised due to functional overload. They all highlighted the importance of the institution to be solidly established and institutionalized before it initiating any technology transfer/developmental activities. Commenting on the issues faced by engineering institutions, one of the respondent stated:

> In the developing countries, one of the important reason why technology transfer initiatives generally fail is due to the fact that academic institutions are inevitably preoccupied with the internal issues of institutional building itself. In such a situation there is a real danger in imposing over ambitious developmental expectations on new institutions where they have yet to be established. The simple rule is that the institutions' own development have to precede their impact on national development. The institution should also have something useful to offer. It remains to be seen whether engineering institutions in the developing countries can have too much of a developmental orientation, however desirable such an orientation may be. Technology transfer activities can lead to extensive over commitment and wide diffusion of interest and attention of the faculty and administration.

Another point of view generally expressed by younger faculty members deal with the "ivory towers" mentality of engineering institutions in the developing countries. They were mainly concerned with the issue of relevance and elitism. They also indicated that before initiating any technology transfer activities, the institution should be well established. Clearly the institution has to focus on its areas of strength.

Summary

It is a common belief shared by all the faculty members interviewed that establishing external linkages with the community is an appropriate mission of an engineering institution. Everyone interviewed was asked the question: "What should be the role of an engineering education institution like the IIT in the transfer and management of technology in a developing country like India and how best can the role be carried out?" All the respondents held the view that production of the right type of engineering graduates is an effective means of technology (knowledge) transfer from engineering education institutions. Furthermore, it was clear from the interviews that most of the respondents felt that engineering education institutions in the developing countries should encourage and develop interaction with industry and the community through various transfer initiatives.

The notion of technology transfer initiatives has generated a distinct set of issues around which positions are being formulated. Debate arises on such issues as the free flow of knowledge, academic freedom and intellectual standards, direction and strength of research, governmenι interference, conflict of interest and commitment and intellectual property rights.

The faculty members interviewed raised two particular issues, which are useful in understanding their underlying conflicts and orientations toward technology transfer activities and initiatives from engineering institutions. Some view technology transfer efforts as dangerous developments; others see them as long overdue. One respondent indicated that external linkages activities are generally undertaken at the expense of academic freedom, intellectual standards and the primary responsibility of a faculty which is teaching. As research funds are awarded by the government and in some case by industry, research topics and areas are completely dictated by the government and the sponsoring industry. In the long run there is politicization of faculty members and the loss of the independence essential to the fulfillment of their primary goals of free teaching, objective inquiry, and conscientious service. Majority of the respondents recognized that those involved in outside activities (like consulting, sponsored research etc.) cannot perform the full measure of their teaching responsibilities and are not generally accessible for student consultation. There was widespread resentment toward faculty members who abused the system by devoting substantial amount of time and energy to outside consulting and in the process neglecting their teaching responsibilities. However, some of the respondents viewed outside consulting and sponsored research activity as an effective technology transfer mechanisms from engineering education institutions and indicated that it has to be promoted. They recognized that a carefully delineated conflict of interest and consulting and technology transfer policies and guidelines and its enforcement will in someway minimize the abuses that are common with external linkage activities.

Most of the respondents identified that the case for an expanded role for engineering institutions in national economic development rests on the recognition that engineering knowledge fuels economic development and that engineering institutions are enormous, publicly supported repositories of technological knowledge and talent. The crucial question for institutions, then, is how to generate faculty interest and involvement in technology transfer activities that will facilitate economic development. On this question, most of the respondents indicated that engineering institutions need to address several complex and interrelated issues related to the technology transfer. They argued that some of the pressing issues include reward and incentive systems; work loads; leadership at all level; consulting and salary policies; and larger questions of institutional values, infrastructures, and faculty morale.

Also, the interviews reinforced the notion that there is no single strategy that will work for all, or even most, engineering institutions and universities. All the respondents agreed that diverse traditions, missions, purposes, constituencies, and external relationships require different approaches and strategies. Most of those interviewed indicated that any technology transfer initiatives from engineering education institutions require substantial amount of faculty time and energy. They recognized that the institution should be solidly established and institutionalized before it initiating any technology transfer/developmental activities.

On the issue of having separate office to support and coordinate faculty efforts related to technology transfer activities, few faculty members were optimistic with the establishment of a Foundation for Innovation and Technology Transfer (FITT) at IIT, New Delhi and saw that as the organizational link between faculty and the industry in the area of technology transfer. However, the majority of the faculty members viewed FITT as distant and unresponsive and indicated that technology transfer initiatives should be left to departments or faculty. They identified the lack of involvement of faculty members and other stakeholders (technical support staff and administrative staff) of the institute in developing a comprehensive technology transfer policy as a major obstacle in successfully initiating technology transfer activities from engineering institutions like the IIT.

Finally, the majority of the respondents expressed general agreement that there is a need for engineering education institutions in developing countries to rethink their role and function in order to increase their involvement with society at large and become a potent force in economic development. There are many ways in which academic institutions can increase their involvement with the community at large and contribute to its development. But few of them can be done in isolation and all these developmental initiatives require some element of technology transfer partnership. Most of the interviewees indicated that the various technology transfer activities initiated by IIT, New Delhi are peripheral and discrete activities, with very limited curriculum connections and faculty involvement. They also observed that at the institution the debate on partnership issues become prominent at times of financial crisis and often the stated purposes of those technology transfer initiatives are ambiguous and vague. Due to this weak rationale for partnerships' initiatives, there is very little long-term commitment or any sense of motivation from the faculty. Most of the respondents viewed that in order to develop and initiate successful and effective technology transfer activities from engineering institutions, there is a need to establish a technology transfer vision and values, define clear purposes of the partnership and develop technology transfer leadership at all level in the institution.

CHAPTER 7

ENGINEERING EDUCATION AND TECHNOLOGY TRANSFER: A PROPOSED CONCEPTUAL MODEL

Introduction

In this chapter, an attempt is made to propose a conceptual engineering education - technology transfer model with a particular focus on developing countries like Nepal. The discussion is based on the literature review, the analyses of field data and the themes which were presented in the preceding chapters. The main focus of the chapter is on the development of the conceptual model of technology transfer that would make engineering education programs in Nepal more relevant and connected with economic development of the country.

Engineering Education, Technology Transfer and Economic Development

Discussions of engineering education, technology transfer and economic development do not have a fixed focus. In an attempt to formulate a common focus on the theme of the importance of higher education to economic development, SRI International (formally Stanford Research Institute) has offered the following broad view of both the process of economic development and the range of roles academic institutions can play in that process:

> Economic development means different things to different people. To some it means helping a failing industry become more competitive. To others it may be recruiting a firm to expand local employment and strengthen the tax base. It can mean developing the capacity of a neighborhood group to generate new enterprises. Increasingly, it connotes high-technology development, or promoting small businesses and entrepreneurial starts-ups, or commercializing new technologies. Broadly, economic development is a process of innovation that increases the capacity of individuals and organizations to produce goods and services and thereby create wealth. This, in turn, can lead to jobs, income, and a tax base for communities, states, and regions.
>
> The ideal college or university involvement in economic development is the strategic use of knowledge-based resources to assist in the development of a local, regional, or state economy. Some institutions have resources that can

> enhance the capacity to produce goods and services and thereby create wealth, jobs, income, and taxes. Appropriate roles can be based on teaching, research, or public service - however an institution can best contribute. (SRI International, 1986, p. x)

Similarly, the Business-Higher Education Forum (1988) which was established in 1978 and whose membership consists of chief executive officers of major US corporations and presidents of research intensive universities conceptualize technology transfer (academia-industry), economic development and the role of academic institutions as follows:

> Exchange of ideas at the very beginning of the research process can lead to selection and formulation of projects with the greatest potential for success - both scientific and commercial. Exchange of information in the course of research can enhance the skills and capabilities of researchers on both sides of the relationship. In this concept, the application of research results is only one aspect of a broader network of knowledge exchanges. Working together in this way, productive university-industry relationships are likely to generate a continuous flow of new knowledge and ideas, rather than the occasional transfer of technology. In short, the old notion of technology transfer as a one-time hand-out from the university to the firm has been replaced by a broader vision, which encompasses an on-going two-way exchange between the partners. In such an environment, sustained relationships between individual researchers, relationships grounded in mutual interests and mutual trust, are of central importance. (p. 17)

The Canadian counterpart of the Business-Higher Education Forum, the Corporate-Higher Education Forum, also subscribes to a more or less similar position on this issue. It sees technology transfer as an important element of contemporary economic development and considers technology transfer as one of the topics to be included in its activities directed towards fostering mutual understanding and building constructive relationships between higher education and industry (as quoted in Bell and Sadlak, 1992, p. 229).

This above concept of economic development, technology transfer and the role of academic institutions seems broader and more integrated than the traditional concept that relates primarily to the teaching function. The interpretation of development from the economic, social or political perspectives has led to conceptualizing different models of technology transfer. Table 1 in Chapter I identifies some of the technology transfer models. Each specific model has its own priority. Some place emphasis on social factors, some on purely economic factors, whereas some models are based on socio-political factors.

The knowledge-based resources embodied in higher education institutions (especially engineering institutions) constitute an essential element in any economic development model. Developing new roles for academic institutions that contribute to economic development can enable these institutions to develop new alliances with industry and business, expand their resource base, enhance their ability to attract and educate students, develop stimulating and useful research opportunities, and fulfill public-service obligations (SRI International, 1986). Transfer of knowledge and technology from academic institutions to industry, business or community constitutes an important role with a higher potential to contribute to economic development. Outlining the increasingly important role played by higher education institutions in the economic development of the United States, SRI International (1986) observed:

> Many factors influence an institution's involvement in economic development and the specific roles it develops. Some factors are internal to the institution, others external. The most important of all appears to be dynamic, entrepreneurial leadership. Other key factors include institutional capacity, strong relations with the public and private sectors, a supportive campus culture, the availability of special resources, supportive administrative policies, and special organizational arrangements. Conversely, the lack of funds and of faculty interest can be key barriers. (p. VII)

Engineering education institutions at least have three general roles in a society:

- teaching
- research
- service directed in solving societal technical problems

The relative emphasis placed on the above three roles varies from country to country and across institutions in a country. In looking at the above three roles, one might suggest that in its teaching and research roles, engineering education institutions in general are already providing a service to the society by producing the technical manpower. In that context, the last roles may be redundant.

In the context of developing countries, there is a general sense of dissatisfaction about engineering institutions and the role they play in national development. Most of the criticism is centered on the ivory tower image of engineering institutions and their inability to connect with the majority of the population. The question of relevance of engineering education and training to a country's development needs has also come into sharper focus.

While this study focuses mainly on the technology/knowledge transfer function of engineering education and training, the idea of transferring knowledge or technology from academic institutions can be traced to the land-grant model of higher education of the mid-1860s in the United States. Land grant institutions in the United States and its agricultural extension model have been identified as a successful initiative in transferring knowledge and technology from academic institutions (Trow, 1993., Bezilla, 1981). The main objective of the agricultural extension services was to disseminate knowledge directly to the farming community in order to meet the needs of the agriculture sector.

The term "technology transfer" has been used in many ways by different people and organizations. Various mechanisms of technology transfer from academic institutions has also been designed. A study by the National Science Foundation (1982) was able to identify 464 different transfer mechanisms at U.S. universities. In the context of technology transfer from academic institutions, a linear or a unidirectional model has generally been used. In the unidirectional model of technology transfer from academic institutions, usually the academic institutions provide the technology/knowledge which is then transferred to various clients - generally industry, business and public users. Bell and Sadlak (1992) termed the linear model as the "center-periphery" model of technology transfer and argued that it was too narrow. They proposed an alternative technology transfer model which puts greater emphasis on *technology transfer as a process between discovery and application,* of which knowledge transfer is a necessary precursor, as opposed to *technology transfer as a commodity* (p. 230).

The American Context

The history of engineering education in the United States has been characterized by progressive tensions (Grayson, 1993). Grayson (1993) further articulated that engineering became a full-fledged member of the education community with the passage of the Land Grant Act in 1862. Since 1862, one of the important ongoing debates with respect to engineering education and its impact in the society has been over the appropriate balance between preparing engineering graduates for immediate usefulness in the workplace and providing them with a more fundamental knowledge that would allow them to continue their education and be more useful in the long run

If we look at the growth and development of American higher education in the past half-century, it has been transformed by a number of powerful social and political forces into a highly organized and functionally diversified enterprise composed of community colleges, teaching institutions, and research institutions. About 200 of the present 3,300 higher-education institutions are now classified as research universities (Hensley and Cooper, 1992). These research institutions have evolved from teaching institution into unique organizations offering distinctive education and sophisticated research activities. Currently about 20,000 engineering faculty educate about 65,000 engineers in some 300 U.S. institutions (Hazelrigg, 1994).

Analysis of the land-grant concept and the technology transfer initiatives from American institutions of higher studies (discussed in chapter IV) provides some useful lessons for new developments and insights in the area of engineering education, technology transfer and economic development.

Lessons Learned

1. The land-grant movement envisioned a new kind of engineering education that aimed to impart scientific knowledge and practical skills and the basic teaching mission was expanded to include service and applied research. With the passage of the First Land Grant Act in 1862, the expansion of engineering education and training has been exceptional.

The number of engineering schools increased from less than two dozen in 1862 to 70 in 1872, a rate of expansion without equal in American education (Grayson, 1993, p.43).

2. Strong federal support in terms of financial inputs and government legislation assured a solid base to maintain and enhance the land-grant concept. After the First Land Grant Act had been passed in 1862, several subsequent Congressional actions were initiated. One of the most important legislative development during 1880s was the Hatch Act of 1887, which provided federal funds to establish agricultural experiments stations. In conjunction with agricultural colleges, the experiment stations formed a system that "extended" agricultural knowledge and research findings to the farmer. These agricultural and engineering experiment station became an important linkage mechanism that provided practical education and transferred useful and practical information to the farmers (Hensley & Cooper, 1992). The Second Land Grant Act of 1890 created the black land grant colleges; and the Smith-Lever Act of 1914 strengthened the out-reach activities of the land-grant universities (Jischke, 1994). The research and education roles of land-grant colleges and universities thus have never been predicated solely on the intellectual interests and curiosities of instructors and researchers. Indeed, service to client groups has been the foundation of federal legislation that created and modified the public agricultural research system over time, and the range of client groups whose needs are to be served has continued to expand (Buttel, Kenney, Kloppenburg & Smith, 1986, p. 149).

3. The land-grant movement emerged in the United States at times of economic prosperity (Jischke, 1994). The financial support extended by the federal and state government were crucial in expanding the service mission of the land grant universities. This highlights the importance of a long-term, stable source of funding in initiating any technology transfer initiatives from academic institutions.

4. Most research universities in the United States have developed or are developing some form of technology transfer programs. However, most of the technology transfer

programs from academic institutions have not been successful to encourage wide faculty participation and are still considered a peripheral activities (Matkin, 1990).

5. The literature on technology transfer between academic institutions and industry is abundant (National Science Foundation, 1982). However, the processes by which universities define, manage, and promote technology transfer initiatives have remained largely unexamined (Rhoades & Slaughter, 1991). They further noted that only few studies have analyzed the impact of new technology transfer policies on traditional faculty practices, such as the use of faculty time and ownership of intellectual property, and none has investigated the processes through which traditional practices are re negotiated to accommodate technology transfer.

6. Most of the technology transfer mechanisms (like industrial/technical liaison, science or technology parks, incubator programs etc.) have been created to structure the diversity of relationships between an academic institution and its environment, to provide a more coherent representation of the institution toward the outside world, and to increase the level of contracts between the academic institution and its industrial environment by mainly exploiting the research potential of the academic institution. The case for an expanded role of an academic institution (especially engineering institutions) in economic development rests on the recognition that knowledge - especially new discoveries and new application - fuels economic development and that colleges and universities are enormous , publicly supported repositories of knowledge and talent (American Association of State Colleges and Universities, 1986).

Most of the technology transfer mechanisms aim to "structure" the technology transfer process. In the process of "structuring" the transfer mechanism, there is also a danger of trying to do everything: like establishing technology/science parks, creating spin-off companies, attracting industrial/business contracts, commercializing research, organizing contact meetings between faculty members and industry personnel, etc.

Increased outside involvement may impair the institution's teaching role (SRI International, 1986, p. 7).

7. Many elements contribute for a successful technology transfer partnership from academic institutions. The 1986 SRI International-AASCU (American Association of State Colleges and Universities) study reported that entrepreneurial leadership was identified as the most important factor to successful institutional involvement in economic development and technology transfer. Other key factors included institutional capacity, strong ties with private and public sectors, a supportive campus culture, well-defined needs, the availability of special resources, supportive administrative policies, faculty incentives, and special organizational arrangements.

Similarly, the SRI-AASCU study (SRI International, 1986) observed that lack of resources and lack of rewards for faculty and staff involvement were key barriers to institutional involvement in economic development. Other key barriers included lack of clear objectives, bureaucratic obstacles, different time dimensions (industry needs vs. academic calendar), conflict of mission, and perceived conflict of interest (p. 45).

The lessons from the American context speak to the effect that even if there is a widespread realization of the importance of technology transfer initiatives from academic institutions in the process of economic development, there is a possibility that during the implementation process the broader perspective may be lost. In this context, the major resource engineering institutions have to offer in the technology transfer partnership is the faculty. The support and involvement of the faculty is crucial in any economic development initiatives. At present, most of the technology transfer initiatives provided by American colleges and universities are provided by peripheral units, with limited faculty involvement (Geiger, 1993; Matkin, 1990; & SRI International, 1986). A crucial question for institutions, than, is how to generate and encourage faculty involvement and interest in technology transfer initiatives. Faculty members too burdened with teaching loads and research involvement rarely want to develop another active technology transfer role.

Internal values and faculty reward and promotion systems emphasize research and scholarly activity with very little consideration for involvement in public service or industry activities.

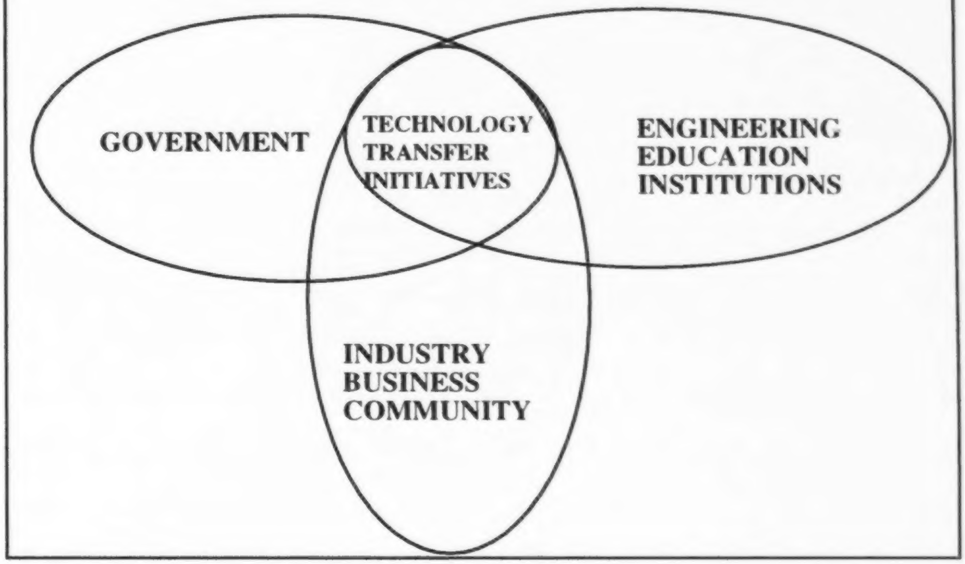
Engineering Education - Technology Transfer Model: A Conceptual Framework

In this conceptual model, the engineering education institutions, the industrial/business community and the government form the three main units responsible which engage in technology transfer initiatives. Figure 4 indicates the three main components of the model. The conceptual framework is developed with a particular focus on developing countries.

The Role of the Engineering Education Institutions

Technology transfer is a function of human beings; in other words, people are at center stage in the process of technology transfer and management. In many instances, transferring a technology requires transferring the knowledge. Thus technology transfer is the application of knowledge. The basic raw material as well as agency for technology transfer are talented people. It will, therefore, be the prime endeavor of the government, engineering education institutions and the industry/business to search, attract, train and continuously retrain and retain talented technical people for all operations of technology management. This is where the role of engineering education institutions in producing talented engineers comes into sharper focus. To a large extent, the concept of "technological literacy" relies on engineering education institutions. These institutions provide two important complementary resources for management and transfer of technology, technical knowledge and skilled workers. Production of competent engineering graduates is an important mode of technology transfer. Fundamentally, there are two main aspects to the transfer process.

Figure 4: Engineering Education - Technology Transfer Model


GOVERNMENT
TECHNOLOGY TRANSFER INITIATIVES
ENGINEERING EDUCATION INSTITUTIONS
INDUSTRY BUSINESS COMMUNITY

1. Production of knowledge
2. Transfer of knowledge

In the context of the developed countries (for example North America), universities see their role as "knowledge production", whereas in the developing countries, engineering education institutions could see their role as "knowledge (i.e. technology) transfer". In both these cases, the successful transfer of knowledge often requires a sustained interaction between the organizations responsible for the generation of that knowledge (academic institutions), on the one hand, and those responsible for its utilization, on the other.

Based on the interviews data and the literature review, three key variables emerge as especially critical in defining the technology transfer roles of engineering education institutions. They are:

1. Technology transfer leadership
2. Motivation (incentives, recognitions and rewards)
3. Training engineering graduates as technology transfer agents: the issue of quality and relevance

The Leadership Issue

It is not surprising that the issue of leadership and commitment are often indicated as key factors in determining the success or failure of any developmental initiatives from academic institutions. From the interviews and the literature review comes the consistent theme that for any technology transfer partnership between engineering education institutions and the community to be successful it must receive support from university administrators, faculty members and leaders in industry and the community. This support must be more than formal or legal: it must be active and participatory. One of the important advantages of participatory leadership is its power to build a sense of community in the academic institutions.

An important implication for practice that emerges from the findings is related to the issue of goal-setting and articulating the mission of engineering education institutions. Many respondents indicated that it is essential for an academic institution to have a sense of what it is doing and where it is going. A goal has a specified or implied end, whereas missions are continuous. Clear targets, specific objectives and goals, and sustained efforts to attain the objectives and goals are all important. In this context, objectives, goals and mission statements serve as foundations on which the institution builds and justifies the ground for its existence within the community and the society. Moreover, the process by which the strategy to articulate the "shared vision" is developed is critical. The involvement of faculty and staff members in developing a technology transfer mission is vital in order to draw their support, understanding, ownership and enthusiasm at every stage of the transfer activities.

Many respondents identified that the lack of involvement and participation of faculty members and other stakeholders (such as students, administrative and technical staff outside user groups etc.) in the development of technology transfer plans and policies was the major hurdle in initiating transfer activities from academic institutions. They also cited ineffective leadership as one of the major constraints on the performance of the institute and academic departments. There is also general consensus among writers in this field that a participatory mode of leadership style is essential in developing and implementing a technology transfer mission in an academic institution (Matkin, 1990; Smilor, Dietrich and Gibson, 1993). Important attributes which are essential for an effective technology transfer leadership are also discussed in chapter VI.

The Motivation Issue

Research conclusions by Matkin (1990) indicate that faculty effort and activity are critical if academic institutions are to engage in an effective technology transfer partnership. One of his findings indicates that very few American universities have a reward or compensation system to encourage faculty participation in technology transfer activities. A critical question , then, is how to motivate faculty members for greater involvement in technology transfer activities?

In any academic institutions, rewards and incentives are the critical factors in motivating faculty involvement in technology transfer initiatives. In this context, the most important tangible rewards in higher education are promotion and salary increments. In the intangible areas, special honors and awards for meritorious service are also important. What, then, are the factors that motivate faculty members to be involved in technology transfer activities?

The motivating factors can be classified as personal and institutional. At a personal level, self-satisfaction and the sense of achievement derived from technology transfer activities and their successes are important factors that motivate faculty members. From an institutional perspective, involvement in technology transfer initiatives should also count as key elements in promotion and confirmation decisions for faculty members. Promotional prospects and career advancement constitute the main motivational forces for faculty members in an academic institution.

The Quality and Relevance Issue

The issue of quality and relevance in engineering education has become a central issue, at least rhetorically, during the 1990s, and it probably will remain a central issue for some time to come in the developing world. However, what is meant by the term "quality" and even if quality is defined, how one attains it is far from clear. Quality is contextual, but is also an objective characteristic of the relationships among processes, objectives, and results (Millard, 1991, p. 137).

During my interviews when I asked the respondents to define and describe the quality of IIT education, most of them responded that it is very difficult to define the quality of IIT education or it can not be defined in any one way. Instead of defining quality, most of the respondents offered some factors that might in their view characterize quality. Some of the factors are listed as follows :

> With an IIT degree it is easier to be admitted in graduate courses in North America.
>
> If we get a B.Tech degree from an IIT, it is not difficult to get a good job in most of the multinational companies in India.
>
> At IIT Delhi the laboratory facilities and the quality of faculty are much superior as compared to the facilities in other engineering colleges in India. That reflects the quality of IIT education.
>
> IIT education has a good reputation in India and aboard and I think that is its quality.
>
> Every one is interested to study at IIT. The entrance examination to get into an IIT is very competitive.

What is interesting is that most of the answers assumed certain implicit definition of quality that would support the characteristics specified rather than explicitly providing the definition and then specifying conditions that would indicate its presence.

In the case of IIT Delhi, there are certain kinds of assumptions (like getting admission in North American university) that persists throughout the campus and these assumptions have been around for a long time quite independent of current problems and issues facing the institute.

In India, both in the public mind and in the self-understandings of the academic community, there exists an undisputable status hierarchy of engineering institutions based on reputation that remains amazingly constant over the years. In this hierarchical relationship, the IIT system comes at the top and the polytechnics are at the bottom. Quality tends to be defined as, or identified with, an institutions' position in this hierarchy. While analyzing the transformation of higher education in the United States in the last two decades, Millard (1991) argued that reputation in academic institutions at best involves a time lag. He articulated that actual performance tends to change more rapidly than reputation. The stability of the hierarchy in India indicates that even time provides no assurance that change in quality will always be generally recognized.

In assessing the stability of reputational rankings of American Universities, Kerr (1994) argued that the reputation, once established, is an institution's single greatest asset. Whatever may be the sources of the reputation to begin with, the public will mostly continue to support the reputation. As an example, Kerr (1994) indicated that over the nearly eighty years from 1906 to 1982, only three universities (Johns Hopkins, Ohio State, and Minnesota) - dropped out from those ranked as the top fifteen - but in each case, not by very much - and only three (Illinois, UCLA, and Cal Tech) were added. And none of these changes occurred rapidly. Kerr (1994) also emphasized that reputational ranking is not a science- it relies on personal judgments, which can be both faulty and prejudiced. In the case of IIT Delhi, reputation is generally related to one broad aspect - national visibility of the IIT system and immediate employment opportunities - but may have very little to do with the effectiveness of the institute or its academic programs in enabling students to fulfill the institute's goals and objectives.

On the issue of relevance, if engineering education institutions in developing countries are to offer engineering programs for national development in which the three functions i.e. teaching, research and service are linked to societal needs, then the emphasis should be on application and transfer of engineering knowledge as compared to production of knowledge and indigenous (applied) research as compared to basic research. The orientation and emphasis, however, should be on producing competent engineering graduates. One of the most enduring contribution of engineering education institutions is through the engineers and technicians they develop in order to manage technology and technological change.

Closely related to the issue of quality and relevance is the issue of curriculum adjustments in which the teaching-learning environment relates to the technological realities of the country and the kind of jobs the graduates will be handling during their professional career.

The Role of Government

Government has an important role to play in financing and managing technology transfer initiatives from engineering education institutions. In most of the developing countries, engineering institutions are established with government grants. The main role of the government, in many countries, in the management and transfer of technology has been in the following areas:

(a) Laying down national priorities and policies on science and technology.
(b) Identification and participation in research and development activities with academic institutions.
(c) Providing support mechanisms particularly tax incentives and benefits for research and development, human resource development and technology transfer.
(d) Promoting national information system for science and technology.

Five Key Roles of the Government

1. To Develop Appropriate Technical Human Capital. Technically trained people who can manage and support technical systems are essential in developing a country's capability to participate effectively in the management and transfer of technology. The base of science and technology consists of trained and skilled manpower at various levels. covering a wide range of disciplines. This immediately raises the question of what types and levels of technical human resources should be trained and how. Unfortunately, there still are no clear answers to this question.

2. To Strengthen the Basic Technological Infrastructure. One key element of technological infrastructure is diffusion of technological knowledge. Here the government has an important role to play in establishing institutional, legal and fiscal structure in engineering education institutions to transfer and diffuse technical knowledge.

3. To Provide some Degree of Research Infrastructure. The key element of research infrastructure should be to help local industry/business assess the relevance of technological advances and help local firms acquire technology. The government should provide significant incentives for private sector (industry and business firm) to invest in R&D activities in engineering education institutions. As the local industries' capabilities mature, research may evolve to develop special new applications of technology or even to develop new technology. However, the important point is that at all times the focus of research needs to be on serving the needs of the productive sector rather than on trying to develop technology for its own sake.

4. To Offer Joint Appointment at Government Engineering Departments and Engineering Education Institutions. This is a novel scheme whereby opportunities are provided for government officials to be attached to engineering education institutions. This joint-appointments system is useful in building teams and will permit a free flow of information and ideas between two units in the technology transfer equation.

5. To Develop Technological Self-Reliance and Promote Indigenous Technology Development and Transfer. For most of the developing countries, self-reliance is at the heart of technological development. The government should aim for indigenous technology development and transfer. For this, the role of different agencies and institutions should be identified, responsibilities assigned and necessary linkages established.

The Role of Industry/Business Community

The goals and values of academic institutions and industry/business differ considerably. For the industrial community the driving force may be profit and proprietary interest in any technology transfer initiatives, whereas for the academic community the main interest is teaching, freedom to publish and respect of peers. The time horizon for any technology transfer partnership between academic community and the industrial community may also be different. Generally the industry would like to have quick and cheap result, whereas the academic community is interested in long time horizon relationship. There is also a mismatch between academic institution's orientation towards basic research and industry's primary orientation towards product improvements.

Many writers argue that the differing cultural norms of the academic and the industrial/business community seem to prevent close interactions (Powers & Powers, 1988; SRI International, 1986; American Association of State Colleges and Universities, 1986 & Dierdonck, Debackere and Engelen, 1990). According to Dierdonck, Debackere and Engelen (1990), by entering into close relationships with industry, academia would be violating its foundations of *communalism, disinterestedness* and *organized skepticism.* For them communalism implies that the body of knowledge generated through scientific activity is subject not to private, but to public ownership (p. 554). This they argued is contradictory to the norms of most industrial organizations. Furthermore, their concept of disinterestedness signifies that scientists have a deep, though detached, interest in the workings of the world, while organized skepticism is a crucial part of scientific methodology itself. Industrial influence upon academic research programs and upon academic research priorities is obviously in conflict with those norms (Dierdonck, Debackere, and Engelen, 1990, p. 554).

The question is "are these differing cultural norms of the academic and industrial community preventing close technology transfer partnership?" In the United States, a long tradition of meeting industrial needs may be traced through the histories of land-grant universities and community colleges. These are discussed in detail in chapter IV. Industry-Institute partnership have used various approaches: Industrial liaison programs, industrial advisory boards, exchange programs for faculty and industry personnel, industry sabbaticals, cooperative industrial attachment programs for students, and more. All these mechanisms identified as institute-industry interactions require an element of collaboration and flexibility from both the parties. From an industry/business perspective, the following key issues should be considered in adopting a flexible approach in the development of transfer relationship with academic institutions:

1. The issue of maintaining a balance between the academic institution's pursuit of research as an integral part of the educational process, and industry's search for useful knowledge and technology to be applied in the development of products, processes and services.
2. The issue of freedom of publication versus secrecy of research findings.
3. The issue of time frame for conducting research. How to organize a program that takes into account the different constraints of industry and the academic institution.
4. The issue of not-invented-here syndrome among industrial researchers
5. The issue of patents and copyrights.

The success of institution-industry interaction however, is heavily dependent on mutual trust and appreciation. And a climate of mutual appreciation can only grow through frequent contacts between individuals in industry and in academia. The industrial or business partner should always be aware that the primary function of a faculty member is teaching.

Summary

"Technology transfer partnership" is a powerful concept. It carries a multitude of meanings and possibilities. It embodies the collaborative, team approach. A conceptual Engineering Education - Technology Transfer Model oriented towards a collaborative team approach is proposed for the purpose of dealing with the use, application and transfer of technology and knowledge. The engineering education institutions, the government and the industrial/business community form the three main units of the proposed model.

The question of *purpose* is critical in any technology transfer partnership from engineering education institutions. The economic arguments for technology transfer partnership has been made in the literature. However, partnership differ in scope, purpose and specific orientations and in the nature of relationship they aspire to. The U.S. land-grant model provides a powerful example of government - academic institution - client groups partnership whose main objective was to disseminate knowledge directly to the farming community on order to meet the needs of the agriculture sector.

In the proposed model, three element are identified as critical in defining the technology transfer role of academic institutions. They are (1) Technology Transfer leadership. (2) Incentives, Recognitions and Rewards for technology transfer activities. (3) Production of competent and relevant graduates.

The role of the government and the user groups (industry, business and the community) should be more as facilitators to help in focusing on social, technical, and economic needs.

Perceptions of the respondents in the field study, case analysis of the technology transfer initiatives from American universities and the ideas of various authors provide support for an integrated approach in the transfer of technology (knowledge) from academic institutions.

Chapter VIII

SUMMARY, CONCLUSIONS, AND IMPLICATIONS

This concluding chapter presents an overview of the study (reflections on the research), a summary of the research design and methodology, a summary of the major findings, and a discussion of the findings. The section on the summary of the major findings is based on responses to the research questions and concerns that relate to the concept of technology transfer, engineering education and training and economic development, and the review of technology transfer initiatives from American universities. Finally, the implications of findings for a developing country like Nepal are also presented in this chapter.

Reflections on the Research

This study was undertaken with a view to develop a technology transfer perspective for the further development of engineering education and training in developing countries like Nepal. As mentioned in chapter I, I worked as project chief in two World Bank financed engineering education projects in Nepal developing and establishing engineering schools. This experience provided a strong foundation for examining the role of engineering education and training in the context of economic development. When we talk about the role of engineering education institutions in national economic development, we assume that engineering knowledge fuels economic development. Especially in the case of developing countries, there is a general impression that engineering education institutions are enormous, publicly supported repositories of technological knowledge and talent. Now the fundamental question that needs to be asked is "do these engineering institutions constitute a significant ***underutilized*** source and resource of technical knowledge and technological innovation?" If the answer to the fundamental question is "yes", then this is where the transfer dimension of knowledge (i.e. technology) from engineering education institutions comes into sharper focus.

As is true of most developing countries, Nepal faces numerous challenges associated with the use and application of technology or technical knowledge. The general purpose of the study was to develop a conceptual framework of planning engineering education as a technology transfer process that would facilitate economic development. Although the idea of an important link between technology transfer, economic development, and the role of engineering education institutions as important institutional agencies of such transfer is not new for the developed countries, it is far from being a reality in the institutional context and development experience of the developing countries. There is an urgent need in Nepal, as in many other developing countries, for implementing engineering education programs designed to improve the management and transfer of technology.

In this study when I talk about technology transfer, I am basically referring to transfer of knowledge. The notion of transfer is not just construed as a process of movement or delivery, it means application and use. Thus if something is never used, then, by my definition, nothing has been transferred. It has only been delivered. Thus, there is no transfer of technology (i.e. knowledge) unless, and until, the technology has been put to use or gets systematically integrated into production processes.

Purpose and Research Strategies

The following objectives and concerns guided the general progress of the study:

1. to define and explain the concept of technology (i.e. knowledge) transfer from engineering education institutions;
2. to examine selected theoretical perspectives on technology transfer and economic development;
3. to describe and analyze critically the various technology transfer initiatives from American institutions of higher education;

4. to review the institutional development of the Indian Institute of Technology, New Delhi, India and review critically the institutional setting and current policies related to technology transfer;
5. to propose a conceptual framework of planning engineering education and training system as a technology transfer process facilitating economic development with particular reference to developing countries like Nepal; and,
6. to outline an approach to implementing the proposed framework for further development of engineering education and training in Nepal.

The study progressed through two distinct phases, each of which involved a particular research strategy. Documentary-based research was followed by a field study. In the first phase, relevant literature concerning the general features and characteristics of different technology transfer initiatives from American universities (chapter 4) was reviewed and critically analyzed. In particular, the land grant university model of technology transfer was explored. The analysis and review of the American context provided an overview of technology transfer orientations that was useful for designing some interview questions for the field study, especially questions related to the organizational forms of different technology transfer initiatives. Furthermore, the review also provided a philosophical orientation that was useful in formulating the conceptual framework of developing engineering education and training system as a technology transfer process in developing countries like Nepal (chapter 7). The major sources of data for the review and analyses were books, journal articles and other documentary materials available in the University of Alberta library or through the inter-library loan service.

Following the completion of the documentary-based research, a field study was conducted in India. The site of the case study was the Indian Institute of Technology (IIT) based in New Delhi. The main objective of the field study was to obtain the perceptions of the faculty members at IIT New Delhi on a wide variety of topics related to the technology transfer functions of engineering education institutions. The aim was to identify various issues that are critical to the task of framing and organizing a coherent institutional response to technology transfer initiatives from engineering education institutions in the context of developing countries. The analysis and review of the technology transfer initiatives from American universities provided some indication about what needs to be considered in planning various technology transfer initiatives from academic institutions. An important limitation of such studies revealed by this review was that they have failed to consider the relevance of their models in the context of the developing countries. The field study in India provided a window to identify the perceived technology transfer opportunities and constraints on the effectiveness of technology transfer partnership between academic institutions and user firms, corporations or institutions in the developing countries and to compare them with the corresponding experience in the developed countries.

During the field study, data were collected mainly through interviews. In total twenty key informants were interviewed, including eighteen faculty members from IIT, New Delhi and two high ranking managers from the industry. Extensive use was made of documentary information about the IIT system in general and about IIT, New Delhi in particular. As mentioned in chapter 3, I stayed at the IIT, New Delhi campus for about two months. The campus being fully residential for staff and students, so in many cases the same faculty members were interviewed on a number of different occasions using an informal, conversational approach.

Qualitative data obtained from documents and through interviews were analyzed by a content analysis process. First the interviews data and qualitative data obtained from documents were scanned and analyzed by grouping them into five main topics (governance and management structure, academic programs, research and development, patents and technology transfer and curriculum and technology transfer). The next step was to identify the themes and to subject each theme to critical examination and search for patterned interrelations among the themes. In conjunction with this analysis, a question that was constantly pursued was could we learn from the case study concerning possible ways of addressing problems associated with technology transfer initiatives from engineering education institutions in Nepal. In general, concepts and themes derived from various sources contributed in developing a conceptual Engineering Education - Technology Transfer Model and an approach to its implementation in Nepal.

Summary of Findings

This section contains the major findings of the study which consist of ideas, concepts and perspectives that relate to engineering education and training, technology transfer and economic development. The findings are summarized as responses to the research questions and concerns. A brief discussion of the developed (the American context) and the developing (the Indian context) countries' perceptions regarding the effectiveness of technology transfer partnership from academic institutions is also presented in this section.

Concept of Engineering Education, Technology Transfer and Economic Development

1.1 What are the general features of technology transfer initiatives from engineering education institutions?

1.2 What are the essential characteristics of technology transfer initiatives from academic institutions in terms of forms, structures, and linkages?

Technology transfer from engineering education institutions is an approach that is organized in a planned and deliberate manner to provide options for moving information, technical knowledge, techniques and innovations from academic institutions to industry, business and community at large. Much of the discussion on technology transfer initiatives from academic institutions has concentrated on institute - industry partnership, and particularly the special efforts that have been made to encourage and facilitate the diffusion of university-based research findings for their eventual application by industries and businesses.

In North America the concept of "technology transfer" which is directly allied with the process, has become a part of various government, industry, and university initiatives. Various mechanisms such as university-based industrial liaison offices, technical assistance programs, research parks, organized research centers, and business incubator programs have been created to facilitate this technology transfer process.

Since the early 1980s, as the conceptual framework of technology transfer initiatives from academic institutions has broadened, the nature, objectives, and essential characteristics have been subjected to intensive analysis. However, a common concern is evident: " is research conducted in academic institutions an underutilized source of industrial innovation; and is there a growing emphasis on the utilization of such research in such a way as to systematically expand and enhance research and development activity?" On this question, two distinct perspectives are identifiable.

According to one perspective, programs associated with technology transfer initiatives from academic institutions are generally considered public service activities and rarely have strong linkages with their teaching and research functions. These transfer initiatives are still organized as peripheral activities and are not viewed as core or integral part of the academic institutions' mandate. Furthermore these initiatives have not been successfully integrated with faculty roles.

Another perspective argues that academic institutions initiate technology transfer partnership mainly to find new sources of income, often as a response to financial constraints. This raises a number of important issues concerning both the objectives of the partnership and mechanisms for transferring technology (i.e. knowledge) from academic institutions. Debate arises on issues such as academic freedom, direction of research, conflict of interest, and conflict of commitment.

Technology Transfer Initiatives in Selected Countries

2.1 What types or forms of technology transfer initiatives have been attempted in the United States and in India?

2.2 what are the factors that are essential for the success of technology transfer initiatives from academic institutions?

2.3 What are the outcomes or consequences due to these transfer initiatives?

2.4 What are the lessons learned?

2.5 What implications might be drawn from these initiatives for planning technology transfer initiatives from engineering education institutions in developing countries like Nepal?

The analysis of the various types of technology transfer initiatives of American academic institutions (chapter 4) and the field study of the institutional development of the Indian Institute of Technology, New Delhi, India (chapter 5) provide a broad spectrum of experiences and insights.

The American experience in technology transfer initiatives from universities shows that the government had a strong commitment to expand its involvement in technology transfer and to encourage by way of funding policies etc. the initiatives, especially in new emerging technologies. However, the study highlights that not all the transfer partnership projects have been successful. Furthermore, there is no single, successful formula in designing programs and partnership initiatives that will promote innovation and technology transfer. In many ways, examples of successful technology transfer initiatives (Silicon Valley, Route 128, Research Triangle Park) are unique. Some relied on strong university-industry interaction (Silicon Valley, Route 128); while some benefited from a strong entrepreneurial tradition and effective technology transfer leadership (Route 128); and in large part, all these initiatives succeeded because of the direct efforts and involvement of the Federal and State government. All these successful initiatives had a common theme: those involved were more willing to perform applied research, to engage in and profit from research and development activities, and to interact with industry and business.

Another interesting insight that came out of the review of the American experiences deals with the institutional setting and institutional pressures, demands, and implications with respect to technology transfer efforts and initiatives. Technology transfer in American universities has many faces. However, the major objective of all the technology transfer programs is to enlarge the financial resource base of the institutions. In doing so, a serious effort is made to develop and encourage those programs that will maximize the revenues from the intellectual property universities produce. A central theme that came out clearly from both the American and the Indian context deals with the extent to which knowledge (i.e. technology) produced by academic institutions should be used as a new source of revenue or profit to support financially struggling institutions. There is also a growing perception within the academic community that this increasing reliance on technology transfer as a significant source of revenue may ultimately subvert the research community's ability to define its research and development agenda. It appears, to many, to contradict some of the fundamental values of academic institutions. It is also raising new and important issues like conflict of interest and conflict of commitment regarding links with industry and business. The real issue, therefore, becomes one of balance: of demonstrating to the public that academic institutions know how to deal with practical problems and contribute to economic development, but at the same time preserving their academic integrity, objectivity and autonomy.

Another important concern revealed by the research deals with the issue of faculty participation in technology transfer activities. In an attempt to coordinate and institutionalize technology transfer initiatives, technology transfer offices on campus have been established. From an organizational perspective it may be an important step, however, an integrated approach to program planning and delivery was usually absent. Very little effort was made to obtain faculty support and commitment before technology transfer initiatives were implemented. Generally these initiatives were formulated by university administrators with very little faculty involvement. As a result, most of the units designed to perform technology transfer activities operate with a minimum of faculty involvement. The issue of integrating technology transfer activities with faculty roles and to recognize technology transfer activities as an important element in faculty reward and promotion systems constitute a vital field where an integrated approach is needed.

By examining the history of various technology transfer efforts from American universities, it is evident that many factors essential for a successful technology transfer partnership from academic institutions are most closely identified with economic development. In this context, entrepreneurial leadership was identified as the most important factor contributing to successful institutional involvement in technology transfer and economic development. Other key factors included institutional capacity and commitment, supportive culture (wide acceptance of technology transfer as a legitimate goal of the institution), availability of resources, supportive administrative policies, faculty incentives and reward policies to recognize involvement in technology transfer and economic development initiatives, and special organizational arrangements to coordinate transfer initiatives.

In the Indian context, the commitment to technology transfer efforts from academic institutions has been minimal. The record of technology transfer initiatives by faculty members of IIT New Delhi has also been very modest. One of the key factors identified as a barrier to technology transfer was the lack of coordination and integration of various sectors (university, industry, business, development projects, government agencies etc.) involved in the process of management and transfer of technology and knowledge. These groups seem to work in a context of mutual isolation or an absence of inter-system linkages. Furthermore, this isolation is aggravated by the absence of a national science and technology plan. With renewed attention to the technology transfer and development function of academic institutions, certain basic questions are being raised. From an institutional standpoint, the crucial question is how to generate faculty interest and involvement in technology transfer activities. Moreover, a number of pressing issues and concerns that influence the development of technology transfer activities includes faculty reward and incentive systems, work loads, technology transfer leadership at all level, consulting and salary policies; and the larger issues of institutional values, infrastructures, and faculty morale.

Proposed Conceptual Engineering Education-Technology Transfer Model

3.1 What are the essential features of the proposed conceptual framework?

3.2 What are the development needs of Nepal which might be addressed through the proposed model?

A conceptual Engineering Education-Technology Transfer Model has been proposed based on the analysis of the technology transfer initiatives from American universities and the field study of the institutional development of the Indian Institute of Technology (IIT), New Delhi, India. In the conceptual model, the engineering education institutions, the industry/business, and the government form the three main social actors responsible for initiating technology transfer activities from academic institutions. The philosophical basis of this framework rests on the view that engineering education institutions in developing countries like Nepal should see their role mainly as "knowledge transfer" rather than "knowledge production". In this perspective, the transfer dimension should occupy an important role with respect to the management and operation of engineering education institutions. Furthermore, the successful transfer of knowledge (i.e. technology) requires a sustained interaction between the organizations responsible for the generation of that knowledge (engineering education institutions), on the one hand, and those responsible for its utilization (mainly government and industry/business).

In the context of developing countries like Nepal, a properly developed Institute-Industry-Government interaction could be beneficial at many levels some of which are :

1. better program quality through ongoing fine tuning in consultation with industry and various government agencies.
2. increased national relevance of the engineering programs.
3. research collaboration with industries to improve their productivity and at the same time raising resources for the Institute and faculty development.

4. a program of well planned and coordinated personnel exchanges between engineers from industries and government departments (mainly related to engineering such as departments of roads, irrigation, works and transportation, housing etc.) and the faculty of the engineering education institutions enriching both sides; it has a potential for modernization of the industry and for contributing to the ability of the Institute to better shape its curriculum to suit the future needs of the industries.

This mechanism of interactions should be based on the sound principle of user and producer relationship in order to bring a sense of realism to the instructional programs thus making it relevant and appropriate to the needs of the country.

CONCLUSIONS

Some of the major problems faced by the engineering education institutions in developing countries like Nepal in framing and organizing a coherent institutional response to technology transfer and economic development issues are discussed below. The measures to resolve them, as suggested here, draw lessons from the American and the Indian experience with various technology transfer initiatives from academic institutions. As presented in the previous chapters, these lessons have been derived from both field research in India and the comprehensive evaluation of technology transfer efforts from American universities.

1. The logic of engineering education institutions becoming involved in technology transfer activities and programs is hardly to be challenged. Many respondents of the field study (the Indian experience) and writers who have conducted extensive research on technology transfer efforts of American universities (Matkin, 1990., Dorfman, 1983. & Geiger, 1993) agree that technology transfer initiatives and programs are not just a passing fad. Rather, it is be a broad-based trend that will bring a significant shift in the way the academic institution views itself and in the way its publics view it (Matkin, 1990). The most difficult but also ultimately the most effective response to technology transfer

initiatives (both in the developed and developing countries) deals with the attempts to integrate technology transfer efforts with faculty roles. Furthermore, the real issue also deals with the question of whether the involvement in technology transfer partnership is consistent with the institution's mission of teaching and research.

2. Education and graduation of qualified students have also been referred to as an effective mode of technology transfer both in the American and the Indian context. The majority of the respondents (from the field study) noted that the teaching function should have the highest priority in academic institutions in the developing countries. They also called for a balanced emphasis in the research and other outreach developmental activities. Furthermore, they emphasized that in the name of technology transfer initiatives or other research and development activities, the teaching function should not be pushed into subordinate position. However, if engineering graduates are an embodiment of technology, critical attention to continuous process of curriculum revision and study programs as representations of knowledge technology would need to be assigned the highest priority.

3. Both the field study as well as the evaluation of American technology transfer efforts point towards a conclusion that a primary emphasis must be placed on building existing strengths in academic institutions and their departments, whether in teaching and in indigenous research activities, rather than spreading the scarce financial and other resources over a large, diversified range of activities. This is especially important in the context of developing countries like Nepal where providing an adequate amount of resources (both financial and trained manpower) for engineering education is one of the major challenges. In recent decades most engineering education institutions in the developing countries have found themselves in a situation which has not encouraged of questioning the value of the research activities; it has been generally accepted that it would be desirable to do research. Engineering education institutions in the developing countries are generally hesitant to identify themselves solely as a teaching institutions. They tend to associate lack of research

activities with lower academic standards and prestige. The extension of educational services in the form of technology transfer initiatives creates increased demands for personnel, for facilities, for funds, for equipment, and for resources in general. This is particularly the case in developing countries where existing facilities and funds are far from adequate, especially for the anticipated demand for research activities. In such a situation, the fundamental question is "how do we approach planning technology transfer activities?".

The Indian case study indicates that the establishment of various research centers (at IIT New Delhi there are 9 research centers) has resulted in spreading the limited resources allocated to the institute. Generally the research centers served as power bases for ambitious faculty and administrators who were primarily interested in their own success. This has also created frustration among the faculty members in the departments, as the faculty members involved in the research centers generally have reduced teaching loads. There were also very little research collaboration and cooperation between the traditional departments and the research centers. A similar conclusion was also articulated by Friedman and Friedman (1984) while discussing the management and operation of "organized research units" (ORU) in American universities. They argued that no research centers should be created unless their goals and objectives complement university missions and strengths.

4. Achieving the goals of technology transfer initiatives from engineering education institutions will largely depend on the interest of the government in solving at least the technological side of developmental problems. Parenthetically, it may be acknowledged here that developmental problems have social, political as well as technological dimensions. We are concerned here with the last of these.

5. Acquisition of competent faculty was viewed as one of the most important criterion for the success of any technology transfer partnership from academic institutions.

IMPLICATIONS

Although one cannot generalize from a single case, the findings and conclusions derived from this study reveal a number of important implications that can be identified for consideration. The major ones relate to the issues which may arise while initiating technology transfer initiatives from engineering education institutions in developing countries.

Implications for Practice: Six Major Issues

On the basis of analysis of technology transfer initiatives from American universities and the field study of the Indian Institute of Technology (IIT), New Delhi, India, a number of important issues (related to technology transfer initiatives) are identified for consideration. The findings have emphasized the following six major issues to be addressed while initiating technology transfer activities from engineering education institutions. Discussion on these issues has appeared often in previous chapters.

1. Issue of institutional leadership (entrepreneurial and technology transfer).
2. Issue of integrating technology transfer activities with the mainstream functions of the institution i.e. teaching and research.
3. Issue of the modes of technology transfer partnership and its effects on the internal institutional patterns of work and working relations.
4. Issue of funding and the respective role of the government , industry and business.
5. Issue of curriculum adjustment.
6. Issue of faculty reward, promotion and incentive policies.

The Leadership Issue

One of the important findings of this investigation have drawn attention to the role of leaders either at the institute or department level in creating a momentum for technology transfer initiatives. Despite the presence of many other factors, the leadership at the department-level, faculty-level, and senior administrators-level remains the key factor in the creation and effective transmission of the technology transfer vision and mission to others in ways that give meaning to their work and their quest.

Moreover, the findings from the review of technology transfer initiatives from American universities and the Indian case study have emphasized the importance of entrepreneurial leaders and policy leaders (for example: president J.E. Wallace Sterling and dean of engineering Frederick Terman at Stanford University, president Bryce Jorden at Penn State University, president Karl Compton at MIT and Ravi Matthai at the Indian Institute of Management, Ahmedabad, India) in mentoring and initiating successful technology transfer partnership. The leadership role involves the crucial functions of championing goals and values, setting direction, and inspiring others to work for the technology transfer mission.

The case study of IIT New Delhi also revealed some areas that may require attention from the leadership within the institute, the faculty and the department. Examples include criteria that dealt with adequate mechanisms of recognition and rewards for faculty members for initiating technology transfer activities, and communication of technology transfer goals and mission to students and other stakeholders of the institution. Another criterion that may constitute a focus for improvement deals with participatory leadership. The interviews with the faculty members at IIT New Delhi emphasized that little efforts was made to obtain faculty or staff support or advice before technology transfer initiatives were adopted (for examples when FITT: the Foundation for Innovation and Technology Transfer was established at IIT Delhi in 1992). The FITT example illustrates that technology transfer initiatives are not as effective when they are made piecemeal in response to specific opportunities or problems. One of the important advantages of participatory leadership is its power to build a sense of community in the institute. Extensive consultation and review by a spectrum of the stakeholders (faculty, staff, students and external user groups), pooling of expertise, mutual accommodation and cooperation, and commitment to outcomes of group deliberations are elements of participatory leadership which can enhance the effectiveness of institute's policies and plans involving technology transfer.

The Integration Issue

Matkin (1990) indicated the most difficult but ultimately the most effective response to technology transfer initiatives from academic institutions is one that attempts to integrate technology transfer activities with faculty roles. The faculty roles consist mainly of two functions: teaching and research. A beginning was made in the 1860s in the U.S. with the land-grant movement to transfer knowledge and technique from academic institutions to the farming community. Land-Grant colleges and universities were established to stress the service mission of academic institutions to client group. The basic concepts of the land-grant idea: democratization of education; applied or mission-oriented research conducted to benefit the people; and service rendered directly to the people through extension agents, continuing education, and other modes of external partnership is still valid today. In the context of developing countries like Nepal the issue of direction of research occupies an important dimension in the technology transfer debate. The majority of those interviewed recognized that in a developing country, technology transfer efforts and initiatives from engineering education institutions should focus more on the application and use of knowledge and research results and should encourage on solving engineering problems of a practical nature rather than pure or abstract subjects. One of the significant dimension of the land-grant concept that the *fruits of research should be taken to the people* (Anderson, 1976, p.4) is still a valid mission or goals of engineering education institutions in developing countries. The majority of respondents called for a balanced emphasis on the research and teaching activities in their departments. However, they all emphasized that research and technology transfer activities should not push teaching into subordinate position.

Modes of Partnership Issue

When technology transfer or external linkages partnership are organized within an academic institutions, it raises a number of important issues concerning the objectives and mechanisms of the partnership. Debate arises on issue such as academic freedom, conflict of interest, and conflict of commitment. There is a general perceptions that academic institutions initiate technology transfer partnership mainly to find new sources of income, often as a response to financial constraints. In this context, faculty members may see conflicts of interest in close ties with industry/business or threats to academic freedom. Concerns have also arisen about the potential loss of institutional independence if engineering education institutions becomes too dependent on industry/business support.

From the Indian case study, it is evident that lack of carefully delineated conflict of interest policies and guidelines and technology transfer plan constitutes a major barrier to institutional involvement in external linkages activities. The majority of the respondents indicated that *visibility* and *diversity* are two common problems for the linkage or extension model in technology transfer initiatives in the field of engineering. Lack of visibility about FITT's existence at IIT New Delhi, its purpose and effectiveness and FIIT's contribution in the technology transfer initiatives is one of the most important shortcoming. With respect to diversity, engineering cover a wide variety of disciplines. To provide technical assistance for the diverse group, extension or linkage programs need critical mass of resources to make the programs viable and self-sustaining. How an institution responds to the technology transfer and development needs depends on what its real capacity to respond is, or could be. Many of the respondents emphasized that engineering education institutions in the developing countries should be very careful in assuming a developmental or technology transfer role before the institution is solidly established and institutionalized.

The Funding Issue

The land-grant model was the first federally supported research program and the only federally funded applied research program until World War II (Buttel, Kenney, Kloppenberg and Smith, 1986). In the United States, after World War II, the federal government began to play a greater and greater role in supporting higher education, initially by sponsoring research (Slaughter, 1990).

A substantial majority of the respondents in the study perceived that two closely linked challenges exist in the field of financing technology transfer activities from engineering education in the context of developing countries like India. These are inadequate resources and inefficient administration. Additional resources to operate technology transfer initiatives will be ineffective unless the efficiency of the institution as a whole is improved. The issue of funding and financing problems in engineering education also are related to inappropriate allocation and inefficient use of available resources, and inadequate mobilization of additional resources. Many respondents at IIT Delhi indicated that the establishment of various research centers has resulted in spreading the limited resources allocated to the institute and in some cases there are also duplication of research efforts at the department and the research center.

Curriculum Design and Adjustment Issue

From a technology transfer perspective, a greater flexibility is needed in curriculum design and adjustment. The findings from this study have emphasized the importance of producing competent, relevant engineering graduates, and education and graduation of students have also been referred to as technology transfer. The case study revealed some areas that may require curriculum adjustment in order to produce engineering graduates who could become technology transfer agents. All the respondents noted that the issue of systematic integration of practical experiences into the engineering curriculum should be addressed. Entrepreneurial and technology transfer attitudes should be promoted throughout engineering education institutions and traditional engineering curriculum in engineering institutions in developing countries should somehow come to grips with the need of entrepreneurship and technology transfer.

Faculty Reward and Promotion Policies Issue

Because the faculty is the heart of an academic institution, the extent of faculty members' involvement in and concern about technology transfer is an important measure of the significance of technology transfer in universities today (Matkin, 1990). Both the field study in India as well as the evaluation of technology transfer efforts of American universities points to a conclusion that technology transfer activities do not get much attention from the academic community and many faculty reward and promotion systems fail to recognize technology transfer activities as important. These factors have tended to push technology transfer activities away from the faculty and thus represent one of the most important barrier to the fuller institutionalization of them (Matkin, 1990).

In order to implement effective technology transfer initiatives from engineering institutions in developing countries, it is also necessary to articulate a coherent institutional stance toward technology transfer and economic development. The findings from this investigation have also drawn attention to the comprehensive focus required if program improvements (technology transfer activities) are to be adequately addressed. The issue of technology transfer leadership at the institute-level, department-level, and faculty-level need to take into account the various pressures and demands (both external and internal) that push themselves on an institution and its leadership. Efforts to enhance effectiveness of technology transfer initiatives should, therefore, focus on a comprehensive set of criteria and issues (for example the six major issues listed above) that cover the major activities and characteristics of the institution. Moreover, in the context of developing countries like India, for effective implementation to occur, it becomes necessary to ask: "Does the institution have the commitment and the capacity to be successful in initiating various technology transfer activities?"

An Epilogue

By examining the technology transfer efforts of American universities and by documenting the institutional development and the technology transfer initiatives of an engineering institute in India, I have tried in this study, to make a comprehensive summary of the issues and concerns surrounding the technology transfer movement. Furthermore, I have also attempted to highlight the subjects of debate as to the kinds of various technology transfer programs which have been developed, the nature of public discussion, and the relationship of engineering education and training with technology transfer and economic development. Similarly, the investigation has also highlighted the breadth and complexity of initiating technology transfer activities from academic institutions.

Because it is both a timely and a relevant issue, technology transfer activities from academic institutions will continue to occupy the attention of practitioners, theorists, and researchers. An emerging technology transfer focus is redefining the role and scope of the academic institution in the United States. In the developing countries the focus is still on teaching. It is hoped that this study will make a contribution to articulating a coherent institutional stance toward technology transfer and economic development and lead to improved performance in engineering education institutions in developing countries.

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APPENDIX A

Land-Grant Institutions in the United States*

ALABAMA
Alabama A & M University
Auburn University

ALASKA
University of Alaska

ARIZONA
University of Arizona

ARKANSAS
University of Arkansas
University of Arkansas, Pine Bluff

CALIFORNIA
University of California system

COLORADO
Colorado State University

CONNECTICUT
Connecticut Agricultural Experiment Station
University of Connecticut

DELAWARE
Delaware State College
University of Delaware

DISTRICT OF COLUMBIA
Federal City Colege

FLORIDA
Florida A & M University
University of Florida

GEORGIA
Fort Valley State College
University of Georgia

GUAM
University of Guam

HAWAII
University of Hawaii

IDAHO
University of Idaho

ILLINOIS
University of Illinois

INDIANA
Purdue University

IOWA
Iowa State University

KANSAS
Kansas State University

KENTUCKY
Kentucky State University
University of Kentucky

LOUISIANA
Louisiana State University
Sourthern University

MAINE
University of Maine

MARYLAND
University of Maryland
University of Maryland, Eastern Shore

MASSACHUSETTS
Massachusetts Institute Of Technology
University of Massachusetts, Amherst

MICHIGAN
Michigan State University

MINNESOTA
University of Minnesota

MISSISSIPPI
Alcorn A & M College
Mississippi State University

MISSOURI
Lincoln University
University of Missouri

MONTANA
Montana State University

NEBRASKA
University of Nebraska

NEVADA
University of Nevada, Reno

NEW HAMPSHIRE
University of New Hanpshire

NEW JERSEY
Rutgers, The State University

NEW MEXICO
New Mexico State University

NEW YORK
Cornell University

NORTH CAROLINA
North Carolina A & T State University
North Carolina State University

NORTH DAKOTA
North Dakota State University

OHIO
Ohio State University

OKLAHOMA
Langston University
Oklahoma State University

OREGON
Oregon State University

PENNSYLVANIA
Pennsylvania State University

PUERTO RICO
University of Puerto Rico

RHODE ISLAND
University of Rhode Island

SOUTH CAROLINA
Clemson University
South Carolina State University

SOUTH DAKOTA
South Dakota State University

TENNESSEE
Tennessee State University
University of Tennessee

TEXAS
Prairie View A & M University
Texas A & M University System

UTAH
Utah State University

VERMONT
University of Vermont

VIRGIN ISLANDS
College of the Virgin Islands

VIRGINIA
Virginia Polytechnic Institute & State University
Virginia State College

WASHINGTON
Washington State University

WEST VIRGINIA
West Virginia University

WISCONSIN
University of Wisconsin System

WYOMING
University of Wyoming

* Anderson (1976)

APPENDIX B

Interview Guide for Twenty Key Informants (Eighteen Faculty Members and Two Industry Personnel)

Position:

Responsibilities:

1. How can the expertise and knowledge embodied in engineering education and training systems be conceptualized as a technology transfer process which can help improve economic growth in developing countries?
2. What should be the role of an engineering education institution like the IIT in the transfer and management of technology in India? How can this role best be carried out?
3. University/Engineering education institution administrators in the developing countries are likely to find themselves facing the need to be responsive to change in the academic tradition and to make policy, organizational, and resource allocation changes to respond to technology transfer. How should such changes be made? Who are the possible "actors" and what are their roles?
4. What are the responses and roles of engineering education institutions toward technology transfer and economic development?
5. Is IIT Delhi an underutilized resource which could assume an expanded role in stimulating the Indian economy through various technology transfer initiatives?
6. How do you plan for research and technology transfer at IIT Delhi.
7. How involved should engineering institutions be in the business end of the transfer process?
8. Was it necessary for IIT Delhi to establish separate office for technology transfer and innovation? What were the reasons for the establishment of the Foundation of Innovation and Technology Transfer (FITT) at IIT Delhi?

9. How necessary are these technology transfer offices ?
10. How effective are the different mechanisms for initiating technology transfer activities at IIT Delhi?
11. From a technology transfer perspective, what should be the nature of research in engineering institutions like the IITs?
12. Do we put emphasis on research which only aims at pushing the frontiers of knowledge, as generally is the case in research universities in industrialized countries, or promote research for technological adaptation and development that relies basically on the use of locally available raw materials and which fits in with the needs of the country's society?
13. Does paid consulting work cause serious conflict of interests for faculty members and institutions?
14. Is there a need to initiate various kinds of outreach, technical assistance, and public service programs from engineering institutions?
15. What is the range of roles engineering institutions can develop in response to meet these new technology transfer challenges?
16. What factors determine how effective engineering institutions will be in the technology transfer partnership with industry, business and the community at large? How are these factors shaped?
17. What are the limitations and obstacles confronting engineering institutions in initiating various technology transfer activities?
18. How can engineering institutions develop effective strategies to guide their involvement in technology transfer and economic development?
19. What are the costs and benefits of involvement in technology transfer and economic development activities? How can such activities support an institution's teaching and research missions?

APPENDIX C

Interview Guide for faculty members involved in some technology transfer activities

Position:

Responsibilities/Activities

The following additional questions were asked for faculty members involved in some technology transfer activities. The questions given in Appendix B were also asked to this category of respondents.

1. What are the problems encountered by faculty members in transferring their know-how to the society.
2. How long have you been involved in the technology transfer activities?
3. What is your motivation to work in these transfer initiatives?
4. Have you discovered something that you thought might have commercial value?
5. Where did you receive your funding for your technology transfer activities?
6. What types of support did you receive from the department, technology transfer office and the institute's administrators?
7. How has the institute encouraged technology transfer?
8. Did you get any help from the patent office?
9. Have you noticed any changes in the direction and nature of research at IIT Delhi in the last ten years?
10. Have you noticed any changes in your relationship with your research colleagues after getting involved in the technology transfer initiatives?
11. Did you noticed any changes in the attitude of funding agencies in the last five years?